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LITHOLOGICAL CHARACTERIZATION

Of CRYSTALLINE BASEMENT ROCK

PROVINCES OF THE INTERIOR

OF THE UNITED STATES

FINAL REPORT
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INTRODUCTION

Precambrian rocks in the midcontinent of the United States are almost everywhere buried beneath generally flat-lying Paleozoic and younger sedimentary rocks. These rocks represent the basement on which the younger sediments were deposited and comprise the continental crust beneath the region. The total area of Precambrian rocks in the midcontinent is nearly comparable to the exposed Precambrian of the Canadian Shield. The rocks are thus a major segment of the Precambrian of North America and are important in deciphering the Precambrian evolution of the continent. The rocks are also important in that they bear the imprint of earlier continental mobility and thus exercise prime control on crustal stability and localized resurgent tectonics.

Our understanding of the Precambrian of the midcontinent is based upon regional gravity and magnetic maps and upon widely separated outcrop areas and samples from irregularly distributed, but numerous, deep wells to basement. Previous work (Flawn, 1956; Muehlberger and others, 1967; Bayley and Muehlberger, 1968) has shown that it is possible to make a map of the buried Precambrian based on drill-hole samples and regional geophysical maps. These papers remain the foundation of our present knowledge. Recent summaries on the geology and geochronology of the mid-continent region have been published by Van Schmus and Bickford (1981) and Denison and others (1984).

Plates 1 and 2 are maps of Precambrian basement rocks of the interior of the United States. Both maps are at a scale of 1:2,500,000. Shown on Plat 1 are the locations of each well to basement and the main basement lithology encountered in each well. Plate 2 is an interpretative basement rock map showing the principal geologic/tectonic provinces in the basement of the continental interior. The map is a revised and updated version of the midcontinent portion of the Basement Rock Map of the United States (Bayley and Muehlberger, 1968). A generalized version of Plate 2 is shown on Figure 1. The geologic overview of the basement that follows is based mainly on the published reports cited in the preivous paragraph and on more recent data. Detailed bibliographies are available in those publications. Updates of more recent work are included where appropriate.

In this report, the following subdivisions of Precambrian time are used:

ERA	TIME (M.Y.)
Late Proterozoic	570-900
Middle Proterozoic	900-1,600
Early Proterozoic	1,600-2,500
Archean	2,500

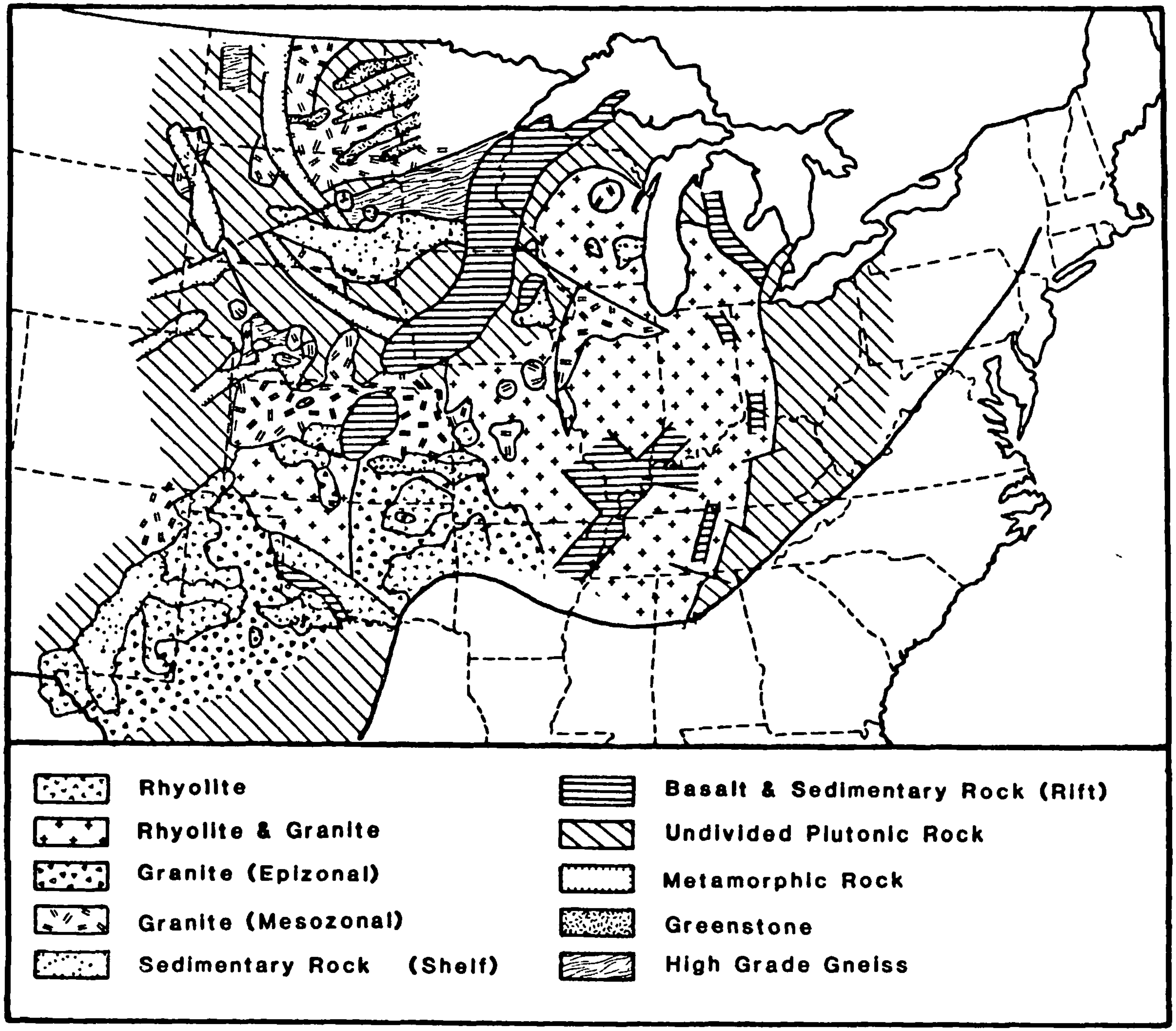

Figure 1: Generalized Basement Rock Map of the Interior of the United States.

DATA ACQUISITION AND EVALUATION

Distribution of Wells to Basement

More than 7,500 wells have been drilled to basement in the midcontinent region of the United States. Most of these have been drilled in the search of petroleum or mineral resources. Their locations are unevenly distributed and tend to be concentrated in areas of specific interests rather than spaced randomly for better regional sample control. Many of these wells were drilled before systematic sample collections were being made and some of the samples are now lost. A further problem of distribution, even in areas where systematic sample collections have been carried out and maintained, is that most wells to basement have been drilled on basement ridges or plains rather than in basins where the basement is deeply buried. This results in additional unequal sample distribution.

Sample Locations

Most information on wells to basement in the mid-continent is available from the various state geological surveys. The surveys are generally the ideal starting place for locating or obtaining basement data. The type of information that is commonly available at survey offices include the following: number and location of wells to basement, depth to basement, basement elevation, total depth, availability and depth interval of samples, drillers logs, geophysical logs, and publications and unpublished reports on the Precambrian.

Other sources of data are from employees of oil companies who have commercial interests in specific areas and from university and other professional personnel who have been involved in basement rock projects. Individuals among the latter two groups are W. R. Muehlberger (University of Texas at Austin), R. E. Denison (One Energy Square, Dallas, Texas), E. G. Lidiak (University of

Pittsburgh), and M. E. Bickford and R. Van Schmus (University of Kansas).

Data Reliability

Data on sample location, sample depth, well logs and similar information can most reliably be obtained from the state geological surveys. Lithologic data is commonly reliable, but depend in part on empahsis and interests of the various state surveys. It is not uncommon, particularly on driller and scout reports or on samples not studied by a trained petrographer, for the basement rock type to be listed unreliably as "granite". In most cases, samples from deep drill holes are in the form of small cutting chips. Textures and mineral proportions of coarse-grained samples can be difficult to determine. Additional problems involve changes in lithology laterally and at depth, weathered samples, and the fact that most wells penetrate only a few meters into the basement. The latter two problems are particularly serious if additional geochemical or geophysical studies are contemplated on the samples or in the deep hole site.

BASEMENT GEOLOGIC PROVINCES

Archean Rocks of the Northern Midcontinent

Archean rocks occur in the subsurface of eastern North and South Dakota. The oldest rocks are granitic and granulitic gneisses that crop out in the Lake Superior region (Sims, 1976) and extend southwestward into the Dakotas along a series of gravity and magnetic anomalies. Radiometric dating of surface samples indicates that the gneisses are at least 3,500 m.y. old. Metamorphism and granite emplacement about 2,700 m.y. ago and a thermal event about 1800 m.y. ago have partly obliterated the earlier geologic history of the gneisses.

Belts of greenstone and related rocks are also extensive in the basement of the eastern Dakotas. Available wells to basement indicate that amphibole schists and gneisses, having mafic and ultramafic igneous antecedents, are the dominant rock types (Lidiak, 1971; Karmer and others, 1981). The rocks are metamorphosed to the greenschist or lower amphibolite facies. Regional relations suggests that the subsurface greenstones are 2,700 m.y. or older.

Granites and granodiorites of Archean age occur between the greenstone belts in the eastern Dakotas. They are part of the Archean greenstone-granite terrane that is widespread on the Canadian Shield. In contrast to the greenstone belts, the granitic areas are characterized by gravity and magnetic lows.

A prominent fault zone of large lateral extent trends west-south-westward from central Minnesota through South Dakota and into southeast Wymoning. (Morey and Sims, 1976). In Minnesota and the eastern Dakotas, this belt separates the greenstone-granite terrane from the older gneissic complex. In Wyoming, this zone is part of the Cheyenne (Mullen Creek-Nash Fork shear zone) belt that separates Archean rocks to the north from Proterozoic rocks to the south.

Early Proterozoic Rocks of the Northern Midcontinent

The west-southwest-trending gravity and magnetic anomalies of the Superior Province are terminated in the central Dakotas by northwest-trending anomalies of the Churchill Province. (Lidiak, 1971). These anomalies imply a northwest trend of the basement, an extension of Proterozoic trends from the Canadian Shield. The presence of linear magnetic and gravity anomalies and scattered wells to basement suggest the presence of three northwest-trending

metamorphic belts containing mafic and silicic rocks of medium metamorphic grade. These belts occur, respectively, in the central Dakotas, in western South Dakota (Black Hills), and in southern South Dakota-northern Nebraska. (Lidiak, 1972). Toward the southwest, in western Nebraska and adjacent areas, metamorphic belts have an apparent southwest strike. An explanation of the change in strike is not immediately evident but may reflect different tectonic or microplate regimes.

Granites are also widespread in the western Dakotas. Apparent radiometric ages on minerals and whole rock samples are in the range 1,650-1,810 m.y., suggesting that a major period of orogeny occurred at that time.

Early Proterozoic Rocks of the Central Midcontinent

Metamorphic rocks of probable early Proterozoic age are apparently present in both southern Nebraska and northern Kansas. Rock types include biotide and muscovite schist and gneiss, quartzite, amphibolite, metarhyolites, and spacialy associated granitic rocks. The metamorphic rocks occur throughout the area either in limited belts or in irregular zones. Grade of metamorphism reached the amphibolite facies. The granitic rocks yield ages of about 1,700 m.y. and are interpreted to represent synkinematic rocks emplaced into the metamorphic terrane. The rocks may be correlative with the well documented Boulder Creek event in Colorado.

Gneissoid granitic rocks are extensively developed in the central midcontinent in the adjacent portions of Nebraska, Colorado, Kansas, Iowa, and Missouri. (Lidiak, 1972; Kisvarsanyi, 1974; Bickford and others, 1981). The rocks are commonly granite to grandiorite in composition and typically have a mild foliation caused by incipient cataclasis.

A period of widespread pervasive shearing and cataclasis is well

developed in these older rocks and apparently occurred between 1,800 m.y. (oldest rocks dated) and 1,480 m.y. ago (age of non-deformed anorogenic granites). Whether the cataclasis correlates with a single period of pervasive regional metamorphism that reached the amphibolite facies or represents a younger metamorphic episode that is distinct from the regional metamorphism has not been determined.

Unconformably overlying the Archean and Early Proterozoic rocks of southeastern South Dakota, eastern Minnesota, and immediately adjacent portions of Nebraska and Iowa is the Sioux Quartzite. The Sioux is a uniform, midly folded, subhorizontal sheet that is composed mainly of silicified quartz sandstone. Pebbles of iron formation in the Sioux suggest that the unit is less than 1,900 m.y. old; underlying rhyolites suggest that it is at least 1,520 m.y. old.

Middle Proterozoic Rocks of the Central Midcontinent

Granitic to quartz dioritic plutonic rocks with ages in the range 1,450-1,480 m.y. occur in Nebraska, northern Kansas and northern Missouri. (Bickford and others, 1981). These rocks are non-foliated and were probably emplaced into the older silicic terrane after the previously-noted pervasive shearing event. The rocks are not associated with known metamorphic belts and are inferred to be anorogenic. They are part of an enormous belt of amorogenic granitic rocks that are widespread in the central and eastern midcontinent.

An anorthosite complex occurs in southwestern Nebraska. The rocks range in composition from anorthosite to anorthositic gabbro and have been subjected to cataclasis and incipient greenschist grade metamorphism. Regional relations suggest that the complex is younger than the 1,800-m.y.-old amphibolite grade metamorphism and older than a period of cataclasis and greenschist facies

metamorphism. This low grade metamorphism is wide-spread in the basement of southwest Nebraska and is inferred to have occurred about 1,170 m.y. ago on the basis of numerous K-Ar and Rb-Sr ages of micas.

The last major rock-forming event in the central and northern midcontinent is the formation of the Midcontinent Rift System, a major belt of basaltic and gabbroic rocks that coincides with pronounced linear gravity and magnetic anomalies and extends from the Lake Superior region southward to Kansas. Flanking basins containing feldspathic and arkosic sedimentary rocks are associated with negative anomalies and occur on both sides of the belt of mafic rocks. The age of the mafic volcanism in the Lake Superior region has been determined to be about 1,100 m.y. This rift zone is more than 1,500 km long and about 65 km wide. It represents a major period of extensional tectonism in central North America during Proterozoic time. Other prominent rift zones are present in the eastern midcontinent, and they are discussed subsequently.

Middle Proterozoic Rocks of the Southern Midcontinent

The basement of southern Kansas, southern Missouri, Oklahoma, and northern Arkansas is underlain almost entirely by an extensive terrane of felsic volcanic rocks and associated eqizonal and mesozonal granitic rocks that formed in the interval 1,300-1,500 m.y. ago; older rocks are apparently not present. The terrane extends across the midcontinent from central Wisconsin and western Ohio at least to the Okalhoma Panhandle and probably as far west as Arizona.

These rocks have been studied in greatest detail in the St. Francois Mountains of southeastern Missouri when alkali rhyolitic ash-flow tuff, trachyte, trachyandesite, and related granitic plutons are exposed. The volcanics occur as roof zones over subvolcanic and epizonal plutons which

have sheet-like, cylindrical, and cone-sheet forms. The rocks show no evidence of penetrative deformation and regional relations, clearly indicate that they formed in an environment removed from orogenic activity.

Rocks similar to those exposed in the St. Francois Mountains are extensive in the subsurface. (Denison, 1981). In northeastern Okalhoma epizonal granites are 1,375 m.y. old. Mesozonal granitic rocks are widespread in southern Kansas and are well sampled along the Nemaha Ridge. More deep-seated granites crop out in the eastern Arbuckle Mountains of southeast Oklahoma where large plutons having ages of 1,375-1,400 m.y. occur. These rocks are the probably mesozonal age equivalents of the eqizonal granites of northeastern Oklahoma.

<u>Middle Proterozoic Rocks of the Southwestern Midcontinent</u>

The oldest radiometric ages obtained from the western Texas-eastern New Mexico area are Rb-Sr ages on granitic gneisses that are about 1,600 m.y. old. These gneisses and associated metasedimentary and metavolcanic rocks have limited distribution and occur mainly west of Figure 1. The mature character of the metasedimentary rocks suggests that they are shelf deposits laid down upon sialic crust. Other granitic gneisses are present in southeastern New Mexico and adjacent Texas. They yield ages of about 1,000 m.y.

Anorogenic granites occupy a large area of northeastern New Mexico and the Texas Panhandle. These rocks are distinguished from the older gneisses mainly by the absence of metamorphic features. Radiometric dates on whole rocks and minerals suggest an age of about 1,300 m.y. for these granites.

A sequence of rhyolites and comagmatic granites, having an age of approximately 1,200 m.y., is widespread in the Texas Panhandle and adjacent eastern New Mexico. Well preserved textures indicate that the rhyolites

are ignimbrites; the associated granites are typical hypersolvus epizonal intrusives in which micrographic textures are common.

The youngest terranes of regionally metamorphosed rocks and associated granitic intrusives occur in the Llano Uplift of central Texas and in the Van Horn area of western Texas. Rocks of the Llano region can be traced as far as 300 km north of the uplift and consist of older quartzo-feldspathic gneisses overlain by hornblende, graphite, mica schists and marbles into which a variety of granitic plutons were emplaced. The metamorphic rocks yield radiometric ages of 1,160-1,170 m.y.; the intrusive granites have ages of about 1,060 m.y. (Garrison and others, 1979). In the Van Horn area, regional metamorphism and pegmatite development occurred about 1,000 m.y. ago. Some of the metarhyolites are apparently older, but their precise age has not been established.

Low-grade metasedimentary and associated basaltic (and diabasic) rocks form extensive subcrops in the subsurface of southeastern New Mexico and western Texas. Limited but well exposed outcrops of the rocks occur in the northern Van Horn and Franklin Mountain areas of Texas and in adjacent New Mexico. In western Texas, the sedimentary rocks are mainly of marine origin, but they become progressively arkosic and non-marine northward in the subsurface. The time of deposition of these rocks is probably slightly in excess of 1,000 m.y. In the Franklin Mountains they are conformably overlain by rhyolites and intruded by granites that have ages of about 1,000 m.y.

Middle Proterozoic Rocks of the Eastern Midcontinent

Western Region. A large portion of the eastern midcontinent extending from central Wisconsin southward into Illinois, Indiana, western Ohio,

Kentucky and Tennessee, is underlain by an extensive terrane of unmetamorphosed rhyolite, trachyte, and epizonal to mesozonal granite. As noted previously, this terrane is extensive and continues through the southern midcontinent as far west as Arizona. The rocks in this terrane from the eastern midcontinent are mainly 1450-1500 m.y. old. However, ages of 1600-1800 m.y. occur in central Wisconsin, and ages of 1340-1400 are present in Oklahoma and immediately adjacent areas. The terrane is characterized by an overall homogeneity and relatively subdued magnetic anomaly pattern. The rocks show little or no evidence of penetrative deformation, although they are locally folded and faulted. They are interpreted to have accumulated in a non-orogenic, possibly extensional cratonic, tectonic environment. No associated orogenic belts have been identified.

Exposures of this terrane in central Wisconsin consist of approximately 1,800-m.y.-old rhyolitic ignimbrites, granophyric granites, and porphyritic granites intruded by 1,500-m.y.-old rapakivi granites. (Van Schmus and others, 1975). Recent work in the subsurface of northern Illinois and adjacent areas (Coates and others, 1983; Hoppe and others, 1983) reveals the presence of a broad belt of northeast-trending anorogenic granite plutons that lie along the northwestern boundary of the 1450-1500-m.y.-old granite-rhyolite terrane. Elsewhere in the subsurface, apparent mineral ages on granites and rhyolites are 1,200-1,500 m.y. Some of the younger dates are apparently minimum ages that have been reduced by later igneous or metamorphic activity.

Unmetamorphosed sedimentary rocks of probably middle Proterozoic age occur in widely separated areas in the eastern Midcontinent. The best known example is the Baraboo Quartzite of southern Wisconsin which was deposited later than about 1,750 m.y. ago. The Baraboo, the previously described

Sioux Quartzite, and similar quartzites in the subsurface are probably correlative and represent widespread sedimentation. The mature sedimentary character of these rocks suggests that they were deposited in a shelf-type environment.

A series of northwest-to north-trending basaltic rift zones occurs in the eastern midcontinent and are delineated mainly by linear gravity and magnetic anomalies. None has been dated but they are similar to and possibly coeval with the previously noted 1,100-m.y. old Midcontinent Rift System. The best documented of these rifts occurs in the Michigan Basin where regional geophysical and geologic relations suggest correlation with the Keweenawan Midcontinent Rift System. The other rift zones shown in western Ohio, Indiana, Kentucky, and Tennessee are not as well documented, but linear geophysical anomalies and sparse well control support the rift interpretation.

Eastern Region. The Grenville Province continues into the United States near the western end of Lake Erie and extends southward in the subsurface through Ohio, Kentucky, and Tennessee. The front is drawn along a series of prominent north-trending gravity and magnetic highs that appear to post-date the anomalies associated with the rift zone in the Michigan Basin. (Hinze and others, 1975; Lidiak and others, 1983). West of the front is the previously--described granite-rhyolite terrane. To the east are medium grade mafic and silicic schists and gneisses, calc-silicate rocks, anorthosites, and two-feldspar granites.

The last main period of metamorphism in the Grenville Province occurred about 1,100 m.y. ago. Age determinations on micas from gneiss, schist, and granite in the subsurface are in the range 800-1,000 m.y. These dates

are in good agreement with mica dates obtained from exposed areas in Canada. These younger mica ages do not, however, date the main orogenic period, but reflect instead later thermal distrubance and deep burial.

The subsurface Grenville front probably does not represent a major Precambrian suture in eastern North America. Geophysical anomalies in both Michigan and Kentucky suggest that Keweenawan-type rift zones extended into the region that is now part of the subsurface Grenville Province. Sparse well control suggest that at least some of the rocks in the rifts were metamorphosed during Grenville orogenesis. The subsurface Grenville front is probably a complex boundary. In some localities it appears to be a fault zone and in others a zone of metamorphic transition.

Late Proterozoic to Early Paleozoic Aulacogens in the Southern Midcontinent

Two prominent aulacogens extend into the craton of the southern midcontinent and are shown on Figure 1. The eastern of these, the New Madrid Rift Complex, occurs in the upper Mississippi embayment and is centered on the intersection of the New Madrid seismic zone and the 38th-parallel lineament (Hildenbrand and others, 1977; Braile and others, 1982). The boundaries of the rift complex are defined by interpretation of geophysical and geological data. Sparse deep well control indicates that pre-Upper Cambrian arkosic sedimentary rocks and basalts occur in the rift zone but are absent outside the rift. (Lidiak and others, 1982). The rift complex owes its origin to late Proterozoic-early Paleozoic plate tectonic events. It is a reactivated structure that currently controls the location of earthquake epicenters in the New Madrid area and has localized intrusive and fault activity during Mesozoic and Cenozoic time.

The second aulacogen shown on Figure 1 is the southern Okalhoma

aulacogen (Hoffman and others, 1974). The boundaries of the rift complex enclose the Anadarko, Ardmore, and Marietta basins and flanking Wichita and Amarillo uplifts. Prominent linear gravity and magnetic highs and lows characterize the structure. The aulacogen is underlain by Precambrian granites which are overlain by a thick bimodal suite of silicic and gabbroic rocks. The silicic rocks consist of rhyolite volcanics and hypbassal granite sills which yield ages of 510-530 m.y. (early to middle Cambrian). The aulacogen continued to be tectonically active throughout Paleozoic time.

BASEMENT AGES AND TECTONIC PROVINCES

The rocks of the midcontinent region are divisible into five general types: (1) plutonic granitic and metamorphic rocks similar to those exposed in the shield areas; (2) anorogenic mesozonal and epizonal granites; (3) rhyolite and epizonal granite; (4) shelf-type sedimentary rocks; and (5) basalt, gabbro, and sedimentary rocks of "rift" type. These five types have regional distribution in the midcontinent and also correspond in a general way to the main tectonic and basement age provinces. Distribution of the principal age and tectonic provinces are shown on Figure 2.

The first type is typical of rocks exposed in the Canadian Shield. The oldest of these rocks are of Archean and early Proterozoic age. They are extensively developed in the northern midcontinent, and they constitute a group of diverse and strongly deformed metamorphic rocks together with massive to foliated granitic plutons, both of orogenic character. Archean rocks occur in the eastern Dakotas and they are clearly buried portions of the Canadian Shield. These rocks are mainly older than 2,500 m.y. and some

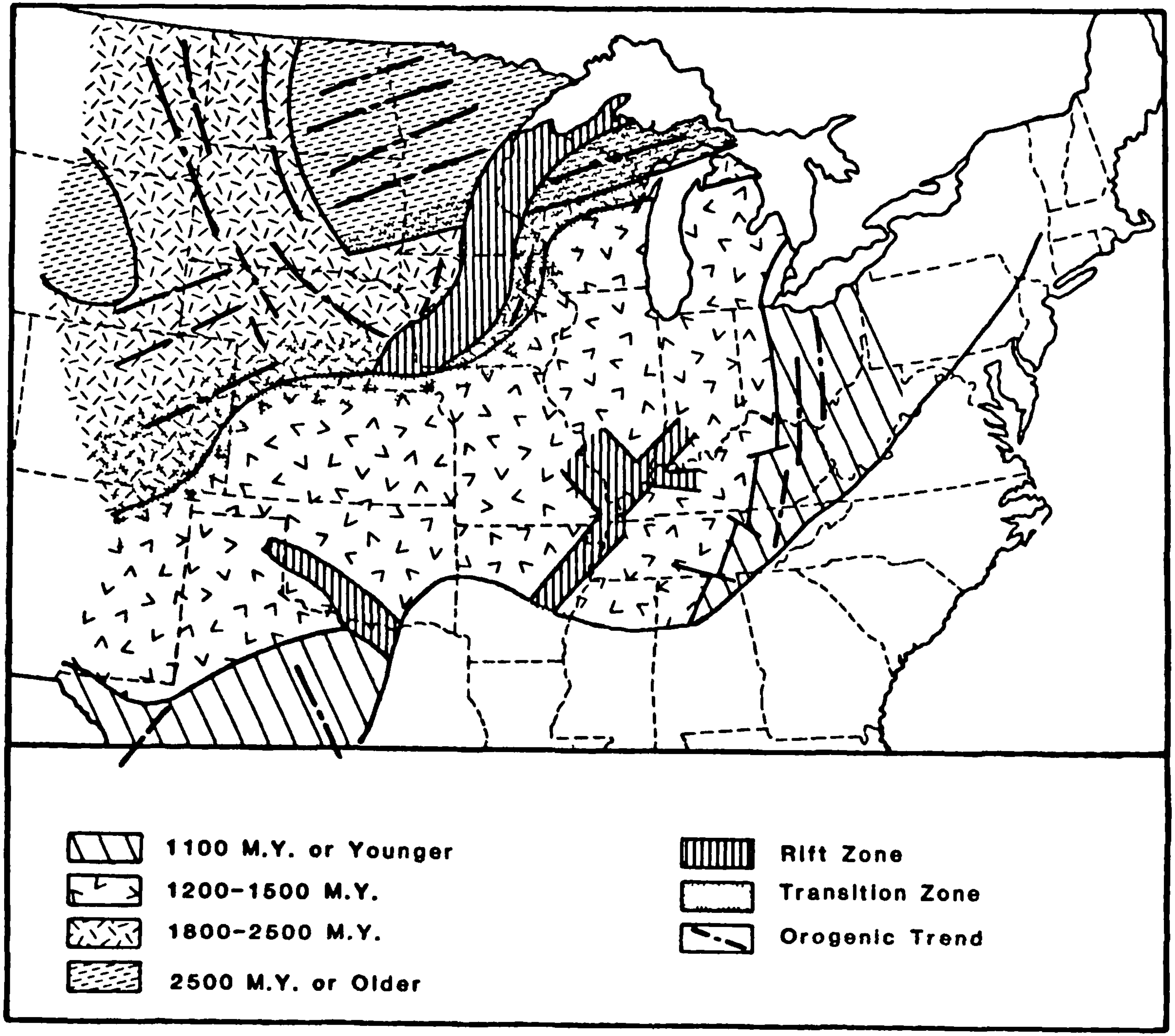

Figure 2: Principal Age and Tectonic Provinces of the Interior of the United States

may be as old as 3,600 m.y. Their marked density and magnetic contrasts allow ready extrapolation in the subsurface. Archean rocks are also present in Wyoming (Fig. 2), and the intervening area of the western Dakotas between the two Archean nucleii are generally regarded as being underlain by Archean crust. The southern boundary of Archean crust probably occurs along a zone that extends from about southern Minnesota west-southwestward to southern Wyoming.

Rocks of early Proterozoic age extend southward from the Canadian Shield into the western Dakotas, Montana, eastern Wyoming, and northern Nebraska. The rocks consist mainly of metasedimentary rocks, minor metaigneous rocks, and foliated to massive granitic plutons. Radiometric ages are mainly in the range 1,600-1,800 m.y. The rocks are characterized by distinct penetrative deformation and are apparently of orogenic tectonic style. Inferred structural trends, based mainly on linear geophysical anomalies, is predominantly northwestward. Southwestern structural trends characterize southern Wyoming, western Nebraska, and Colorado, and these trends presumably represent distinct tectonic regimes. The southern boundary of these early Proterozoic provinces occurs along on apparent borad transition zone that extends from northern Wisconsin through southern Nebraska and into Colorado (Fig. 2). However, northwest-trending magnetic anomalies of subdued amplitude pervade much of the central and southern midcontinent and continue as far south as Oklahoma and southern Missouri. These anomalies probably indicate that the early Proterozoic continental crust extends into the southern midcontinent and underlies the anorogenic granites and rhyolites.

The second main type of midcontinent basement is characterized by anorogenic mesozonal to epizonal granitic plutons that formed 1,450-1,500 m.y. ago. They are associated with minor metasedimentary and metaigneous rocks. These rocks extend from Arizona through Kansas and into the northeastern midcontinent. On Figure 2 they form a discontinuous zone that includes portions of the northern part of the 1,200-1,500 m.y.-old terrane and the adjacent transition zone. The appearance of these rocks marks a significant change in the tectonic development of the midcontinent. Prior to 1,600 m.y. ago, the central interior of North America was dominated by eugeosynclinal sedimentation and orogenic tectonic styles. Subsequently, the region was characterized by cratonic stabilization, extensional tectonism, anorogenic igenous activity, and shelf-type sedimentation.

The third type of basement consists of large tracts of rhyolite and associated epizonal granite. These rocks occur mainly in the southern and central parts of the 1,200-1,500-m.y. terrane shown on Figure 2. Radiometric ages of these rocks range from 1,200 to 1,500 m.y. The origin of these silicic igneous rocks remains obscure, but they appear to be underlain by older continental crust, are not associated with any significant volume of other volcanic or sedimentary rock, and appear to be preserved mainly in structural depressions. Together with the previously-described anorogenic granites (type 2), these rocks comprise about one-half of the areal distribution of the basement in the midcontinent region. The abundance of these rocks is a major difference between the buried Precambrian and the shield areas.

The fourth major type consists of mature quartzose sandstones that represent shelf-type sedimentation. Such rocks are not abundant but occur sporadically throughout the midcontinent. The best known examples are the

Sioux and Baraboo quartzites of the northern midcontinent. These two quartzites were deposited approximately 1,700 m.y. ago and are significant as they represent sedimentation on a stable craton. Other shelf-type sedimentary deposits of younger age are known to be present in Nebraska, Kansas, eastern New Mexico, and the Texas Panhandle.

Rift-type basalts, gabbros, and associated arkosic sedimentary rocks represent the fifth main rock association. The Keweenawan Midcontinent Rift System that extends from Lake Superior to Kansas is the best known example, It is widely regarded as being an abortive continental rift that formed 1,100 m.y. ago. Other rifts of apparent similar age are present in the eastern midcontinent. These rifts represent an important period or periods of extensional tectonism in the Precambrian development of North America.

Marginal to the 1,200-1,500 m.y.-old granite-rhyolite terrane of the eastern midcontinent is the subsurface Grenville Province of Ohio, Kentucky, and Tennessee. These rocks consist of plutonic granitic and metamorphic rocks (type 1) that represent orogenic development approximately 1,100 m.y. ago marginal to a stable craton. Similar rocks occur in the Llano Uplift and Van Horn areas of Texas.

Two aulacogens are present in the southern midcontinent that had their origin in plate tectonic regimes operating along the southern margin of the continent. The New Madrid Rift Complex of the upper Mississippi embayment developed in late Proterozoic-early Cambrian time and continues to be active as a reactivated structure. The southern Oklahoma aulacogen is an early to middle Cambrian structure.

CONFIGURATION OF THE BASEMENT SURFACE

The configuration of the basement surface in the midcontinent is shown on Figure 3. The surface consists of a broadly undulating plain and a number of basisn and uplifts, the most prominent of which are shown by symbol on Figure 3. Many of the basins show considerable subsidence and accumulation of sedimentary rocks, but the sedimentary units have not been strongly folded, intruded, or metamorphosed. Basin development occurred mainly in Phanerozoic time, but most of the interior basisn have a Precambrian signature. (Lidiak, 1982). The uplifts or ridges are generally subdued and covered by a relatively thin sedimentary veneer. Locally they may display appreciable basement relief. Several large fault zones, which involve considerable displacement of the basement during the Phanerozoic, are present in the midcontinent. Among the most prominent are the faults along the 38th-parallel lineament, along the Nemaha Ridge, and in the Anadarko Basin and associated uplifts.

Compared to the orogenic fold belts encircling the craton, the midcontinent region has exhibited relative stability since the beginning of Paleozoic time. Detailed studies reveal, however, a long and locally complex history of movements which have produced unconformities, folds and flexures, and comples faults that involve both the basement and the overlying sedimentary cover.

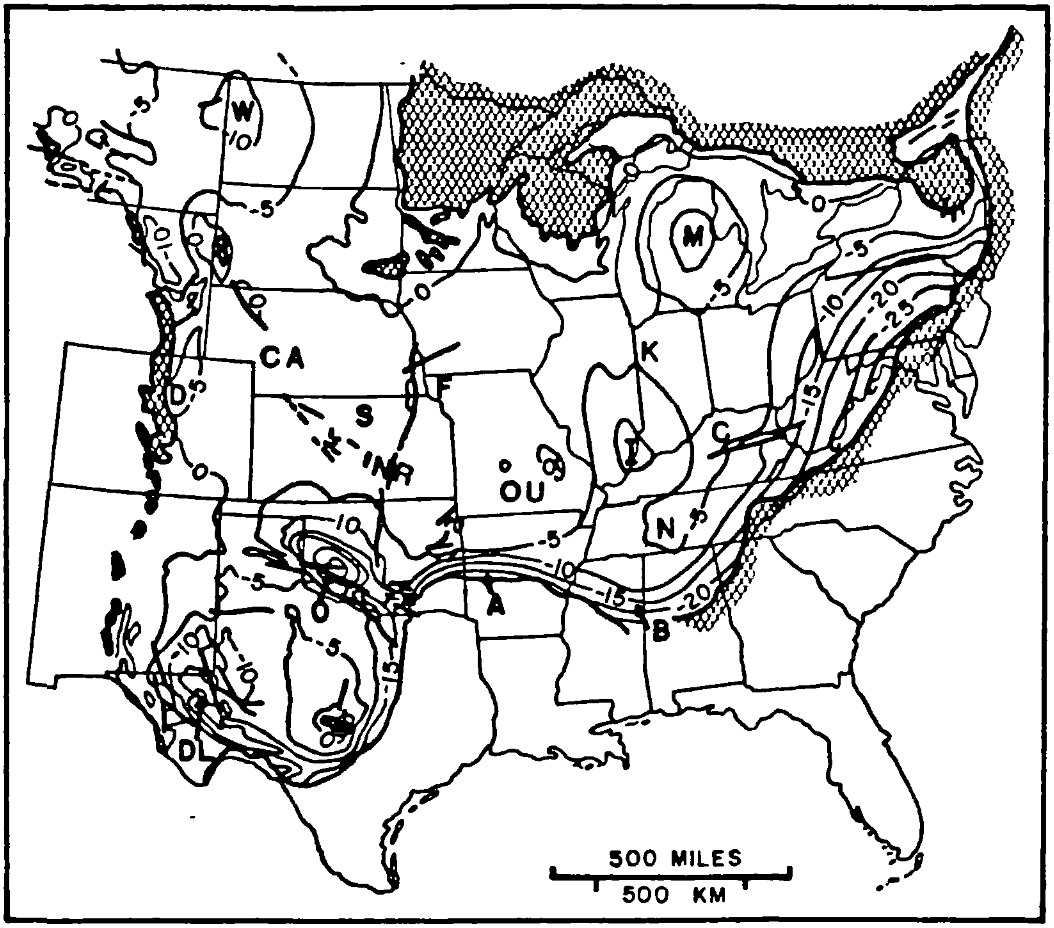

Figure 3: Configuration of the Basement Surface of the Interior of the United States. Contours are in thousands of feet on the buried basement surface. Basin abbreviations: A-Arkoma, B-Black Warrior, DL-Delaware, D-Denver, F-Forest City, I-Illinois, M-Michigan, O-Southern Oklahoma, S-Salina, W-Williston. Exposed Precambrian, cross-hatched pattern. Ouachita system, dotted pattern.

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APPENDIX 1

List of Wells to Basement

ARKANSAS

Benton County:

Location	Rock Type
33-18N-33W	Rhyolite porphyry
11-19N-33W	Microgranite porphyry
25-19N-33W	Micrographic granite

Carroll County:

30-21N-25W	Micrographic granite

Conway County:

34- 6N-17W	Granitegneiss and metadiorite

Crawford County:

14-10N-32W	Micrographic granite

Faulkner County:

6- 7N-12W	Granite and diabase

Franklin County:

17-10N-27W	Microgranite porphyry
21-10N-28W	Granite
9- 9N-28W	Micrographic granite

Logan County:

15- 6N-28W	Metarhyolite

Madison County:

6-16N-27W	Rhyolite porphyry
3-16N-26W	Metarhyolite
13-15N-26W	Rhyolite

Mississippi County:

14-12N- 9E	Arkose and granitic gneiss

Newton County:

28-13N-22W	Microgranite porphyry

Searay County:

18-14N-16W	Granite

EASTERN COLORADO

Adams County:

Location	Rock Type
26- 2S-67W	Biotite gneiss

Baca County:

Location	Rock Type
8-30S-50W	Latite porphyry
32-29S-48W	Quartz monzonite
12-33S-50W	Quartz monzonite
3-35S-50W	Granite
22-34S-48W	Granite

Bent County:

Location	Rock Type
17-27S-51W	Quartz monzonite
15-26S-52W	Granodiorite
14-26S-53W	Quartz monzonite
35-27S-52W	Altered olivine basalt

Fremont County:

Location	Rock Type
16-18S-69W	Biotite gneiss

Huerfano County:

Location	Rock Type
24-26S-68W	Hornblende-quartz-microcline-plagioclase gneiss and biotite-plagioclase-hornblende gneiss
30-26S-63W	Granite
6-26S-64W	Giotite gneiss and schist
32-26S-64W	Biotite gneiss

Kiowa County:

Location	Rock Type
1-17S-50W	Tourmaline-bearing mica schist
16-18S-46W	Micaceous quartzite

Kit Carson County:

Location	Rock Type
33- 6S-44W	Biotite schist
31- 6S-42W	Mica schist

Larimer County:

Location	Rock Type
19- 8N-68W	Biotite gneiss

Las Animas County:

2-33S-60W	Granitic gneiss
2-35S-52W	Quartz monzonite
32-34S-56W	Quartz monzonite
30-27S-61W	Granodiorite
19-26S-62W	Altered biotite gneiss
31-34S-63W	Quartz monzonite
7-33S-57W	Quartz monzonite
24-26S-63W	Biotite gneiss
12-28S-52W	Dacite crystal vitric tuff
9-29S-63W	Porphyritic quartz monzonite
16-33S-63W	Granitic gneiss

Logan County:

26-11N-53W	Granodiorite
3- 8N-54W	Biotite gneiss
23-10N-53W	Quartz monzonite
30- 9N-53W	Augen gneiss
16- 8N-53W	Hornblende-biotite gneiss

Morgan County:

11- 6N-55W	Quartz monzonite
32- 3N-55W	Leuco-granodiorite

Otero County:

30-26S-57W	Rhyolite crystal vitric tuff
24-25S-56W	Amphibolitic gneiss
3-24S-59W	Microcline granite

Phillips County:

30- 8N-43W	Granodiorite

Prowers County:

4-24S-43W	Altered muscovite gneiss
12-24S-44W	Quartz monzonite

Pueblo County:

6-18S-64W	Biotite gneiss
11-19S-65W	Granitic gneiss
4-20S-67W	Granitic gneiss
9-25S-64W	Granite gneiss
25-24S-61W	Granitic gneiss
13-23S-68W	Hornblende-granitic gneiss
30-21S-65W	Granite gneiss

Washington County:

7- 2S-52W	Granitic gneiss

Washington County (continued)

28- 1S-49W	Granitic gneiss
34- 1N-49W	Granitic gneiss

Weld County:

19- 8N-61W	Granodiorite
27- 8N-66W	Metaquartzite
12- 8N-60W	Quartzite
18-10N-56W	Granite
1-11N-59W	Biotite granitic gneiss

Yuma County:

10- 5N-46W	Granite
8- 1N-48W	Hornblende granitic gneiss
21- 2S-43W	Rhyolite felsite
2- 2N-48W	Biotite gneiss
31- 4N-46W	Biotite gneiss
21- 4N-48W	Quartz monzonite
19- 1S-47W	Hematite-cemented quartz arenite
1- 3S-48W	Biotite gneiss

ILLINOIS

Boone County:

Location	Rock Type
28-43N- 3E	Biotite granite

Clinton County:

Location	Rock Type
33- sN- 1W	Rhyolite or microgranite

De Kalb County:

Location	Rock Type
35-41N- 5E	Biotite granite

Du Page County:

Location	Rock Type
9-39N- 9E	Granite

Fayette County:

Location	Rock Type
28- 8N- 3E	Rhyolite porphyry

Hamilton County:

Location	Rock Type
6- 6S- 7E	Biotite granite

Henderson County:

Location	Rock Type
14- 9N- 5W	Biotite granite

Henry County:

Location	Rock Type
30-16N- 1E	2 Feldspar biotite granite

Johnson County:

Location	Rock Type
34-13S- 3E	Quartzitic Sandstone, some siltstone

Pike County:

Location	Rock Type
15- 4S- 5W	Mt. Simon Sandstone, Rhyolite porphyry
21- 5S- 4W	Leucocratic microgranite or granophyre

Pope County:

Location	Rock Type
2-11S- 6E	Eu Claire Fm (sandstone), Mt. Simon Sandstone

Putnam County:

3-32N- 2W	Highly altered 1 feldspar granite

Stephenson County:

18-29N- 6E	Granite porphyry

Washington County:

35- 3S- 2W	Granite

Wayne County:

3- 1S- 7E	Rhyolite porphyry or microgranite

Will County:

20-35N- 9E	Biotite granite

Winnebago County:

24-44N- 2E	Biotite granite

INDIANA

Allen County:

Location	Rock Type
33-29N-12E	Basalt
14-29N-14E	Basalt

Fayette County:

Location	Rock Type
32-13N-13E	Rhyolite or microgranite and arkose

Fulton County:

Location	Rock Type
32-29N- 1E	Micro Granite and granophyric granite

Henry County:

Location	Rock Type
12-16N-11E	Granophyric granite and sparse granite in Mt. Simon

Howard County:

Location	Rock Type
32-24N- 5E	Sparse granite in Mt. Simon and altered granite

Jay County:

Location	Rock Type
29-24N-13E	Basalt(?), granite, limestone
29-24N-13E	Rhyolite

Lake County:

Location	Rock Type
14-37N- 9W	Sedimentary rock, Mt. Simon sandstone, Biotite granite

Lawrence County:

Location	Rock Type
20- 5N- 2E	Basalt, rhyolite(?), granite(?)

Marshall County:

Location	Rock Type
21-34N- 3E	Basalt, biotite schist, hornblende schist

Porter County:

Location	Rock Type
16-35N- 5W	Rhyolite
28-37N- 6W	Biotite granite

Porter County (continued)

29-37N- 6W	Altered granite
25-37N- 7W	Altered and fresh biotite granite

Steuben County:

15-38n-14E	Granite with some basalt

Switzerland County:

4- 2N- 1W (?)	Arkose(?), Microgranite

Wabash County:

25-29n- 6E	Microgranite

Wayne County:

23-15N-13E	Microgranite, granophyric granite

IOWA

Allamakee County:

Location	Rock Type
11-100N- 4W	Granite reported at 728 feet
29-99N- 3W	Granite reported
29-99N- 3W	"Granite" reported
29-99N- 3W	Presumably granite
29-99N- 3W	Altered biotite granite below Red Clastics

Boone County:

32-84N-27W	Altered Oligoclase leucodiabase

Calhoun County:

6-89N-31W	Altered biotite granite and microbreccia
17-89N-31W	Predominantly microbreccia; some gneiss and schist and leucogranite; one grain devitrified glass
35-89N-31W	Sandstone, shale and some carbonate

Cedar County:

6-80N- 2W	Sandstone possibly Red Clastics

Cerro Gordo County:

3-96N-20W	Altered diabase, basalt and gabbro (one grain practically chlorite schist.)
10-96N-20W	Altered diabase and basalt
16-96N-20W	Altered diabase

Clay County:

35-97N-37W	Norite and granitic country rock

Clinton County:

22-81N- 6E	Altered biotite granite

Dallas County:

1-79N-29W	Altered diabase
11-79N-29W	Altered diabase
12-79N-29W	Altered diabase
12-79N-29W	Altered diabase
18-79N-28W	Altered diabase
26-79N-29W	Plagioclase-pyroxene diabase

Des Moines County:

16-69N- 2W	One report slate underlying quartzite. Another report sandstone and shale

Dubuque County:

7-89N- 3E	Altered potash
7-89N- 3E	Biotite granite
24-89N- 2E	Potash-leucogranite, bordering on leucosyenite
24-89N- 2E	Perthitic potash biotite granite
30-89N- 3E	Sandstone

Fremont County:

23-68N-41W	Sandstone etc., probably R.C.

Ida County:

35-89N-40W	Biotite granite

Kossuth County:

2-95N-29W	Altered perthitic potash biotite granite

Linn County:

21-83N- 7W	Quartzitic sandstone

Lyon County:

5-99N-45W	Quartzite with intercalated volcanics
5-99N-45W	Quartzite with apparently alternating zones of rhyolite or tuff
9-98N-47W	Sandstone with carbonate cement
16-100N-45W	Argillaceous quartzite with intercalated rhyolite or tuff
18-98N-47W	Sioux quartzite or "granite"
18-98N-47W	Predominantly sandstone, possibly quartzite at bottom of hole

Marshall County:

10-83N-20W	Red Clastics

Osceola County:

13-99N-42W	Sandstone probably Red Clastics

Page County:

25-68N-37W	Altered biotite granite some perthitic

Plymouth County:

16-92N-45W	Quartz porphyry(?) at 960 Gneiss(?) at 1060 Schist at 1560

Pocahontal County:

17-90N-31W	Altered microbreccia and oligoclase biotite monzonite
19-90N-31W	Altered, microbrecciated biotite granite
25-90N-32W	Biotite oligoclase monzonite
29-90N-31W	Predominantly biotite gneiss and granite, some diabase
31-90N-31W	Much altered oligoclase diabase; also, oligoclase, biotite monzonite & hornblende gneiss
35-90N-32W	Biotite granite some slightly gneissic, some grains syenite or monzonite, glassy basalt and micro breccia
35-91N-31W	Carbonate bearing microbreccia; some biotite gneiss, altered diabase and biotite granite
36-90N-32W	Predominantly altered breccia and microbreccia some lithic fragments; a little basalt and gabbro
36-90N-32W	Quartz-oligoclase-biotite gneiss; smaller amounts of diabase and microbreccia

Poweshiek County:

16-80N-16W	Orthoquartzite

Sioux County:

26-97N-45W	Quartz porphyry alternating with sandstone or quartzite
26-97N-45W	Rhyolite porphyry

Story County:

6-83N-22W	Typical Red Clastics

Webster County:

4-90N-30W	Shaly, carbonaceous, mixture

Webster County (continued)

10-90N-27W	Product of complete alteration of basalt or diabase
10-90N-27W	Amygdaloidal basalt
19-89N-28W	Altered diabase

Winneshiek County:

30-98N-7W	The one available sample at 2500' is olivine gabbro

Woodbury County:

29-89N-47W	Gneiss or schist

KANSAS

Allen County:

Location	Rock Type
13-26S-17E	Epizonal granite
26-24S-18E	Epizonal granite
14,34-25S-19E	Epizonal granite

Atchison County:

13- 7S-20E	Mesozonal granite

Barber County:

29-31S-10W	Epizonal granite
13-33S-13W(?)	Epizonal granite

Barton County:

11-16S-15W	Mesozonal granite
11-16S-14W(4 wells)	Mesozonal granite
11-16S-13W(7 wells)	Quartzite
11-16S-13W(4 wells)	Mesozonal granite
11-16S-12W(5 wells)	Mesozonal granite
11-16S-12W(7 wells)	Quartzite
11-16S-11W(6 wells)	Mesozonal granite
11-16S-11W(3 wells)	Quartzite
25-17S-15W	Mesozonal granite
30-17S-15W	Mesozonal granite
30-17S-14W(5 wells)	Mesozonal granite
30-17S-13W(4 wells)	Mesozonal granite
2-17S-13W	Quartzite
2-17S-11W(3 wells)	Mesozonal granite
2-17S-11W(6 wells)	Quartzite
33-18S-15W	Quartzite
33-18S-15W(8 wells)	Mesozonal granite
33-18S-14W(4 wells)	Quartzite
33-18S-13W(3 wells)	Quartzite
22-18S-13W	Mesozonal granite
6-18S-13W	Mesozonal granite
6-18S-12W	Mesozonal granite
6-18S-11W(5 wells)	Mesozonal granite
6-19S-15W(5 wells)	Mesozonal granite
6-19S-15W(5 wells)	Quartzite
6-19S-14W(4 wells)	Mesozonal granite
17-19S-15W	Rhyolitic-dacitic volcanics
20-19S-13W	Mesozonal granite
28-19S-13W	Mesozonal granite
28-19S-12W	Mesozonal granite
28-19S-11W(3 wells)	Mesozonal granite
17-19S-11W	Quartzite
2-20S-15W	Rhyolitic-Dacitic Volcanics
2-20s_14W(3 wells)	Mesozonal granite
31-20S-14W	Rhyolitic-Dacitic Volcanics

Barton County (continued)

25-20S-14W	Rhyolitic-Dacitic Volcanics
25-20S-13W(3 wells)	Rhyolitic-Dacitic Volcanice
25-20S-13W(3 wells)	Epizonal granite
11-20S-13W	Mesozonal granite
11-20S-12W(4 wells)	Mesozonal granite
34-20S-12W	Epizonal granite
34-20S-11W(7 wells)	Mesozonal granite
1-20S-11W	Rhyolitic-Dacitic Volcanics

Bourbon County:

23-26S-23E	Epizonal granite

Brown County:

8- 1S-14E	Mesozonal granite

Butler County:

1-24S- 3E	Mesozonal granite
33-25S- 3E	Mesozonal granite
22-29S- 3E	Mesozonal granite
4,16-23S- 4E	Quartzite
1-23S- 4E	Mesozonal granite
36-24S- 4E	Mesozonal granite
18-24S- 4E	Quartzite
18-26S- 4E(5 wells)	Mesozonal granite
18-27S- 4E(3 wells)	Mesozonal granite
18-28S- 4E(3 wells)	Mesozonal granite
18-29S- 4E(4 wells)	Mesozonal granite
18-23S- 5E(9 wells)	Mesozonal granite
6,36-24S- 5E	Mesozonal granite
2,8-25S- 5E	Mesozonal granite
29,33-25S- 5E	Quartzite
20-26S- 5E	Mesozonal granite
4-26S- 5E	Quartzite
30-23S- 6E	Mesozonal granite
6-24S- 6E	Mesozonal granite
15,29-26S-8E	Mesozonal granite
21-28S- 8E	Mesozonal granite

Chase County:

18S- 6E(6 wells)	Mesozonal granite
19S- 6E(3 wells)	Mesozonal granite
25-20S- 5E	Mesozonal granite
24,25-21S- 5E	Mesozonal granite
21-22S- 6E	Mesozonal granite
3,32-18S- 7E	Mesozonal granite
19S- 7E(6 wells)	Mesozonal granite
20S- 7E(9 wells)	Mesozonal granite
24-19S- 9E	Mesozonal granite
15-22S- 9E	Mesozonal granite

Chautauqua County:

17,28-32S-10E	Rhyolitic-Dacitic Volcanics
13-35S-10E	Rhyolitic-Dacitic Volcanics
26-34S-11E	Rhyolitic-Dacitic Volcanics
28-34S-13E	Rhyolitic-Dacitic Volcanics

Cherokee County:

20-31S-22E	Epizonal granite
13,17-33S-23E	Epizonal granite
1,12-35S-23E	Rhyolitic-Dacitic Volcanics
2,12-35S-23E	Mafic Intrusives
24-32S-25E	Epizonal granite

Clay County:

14- 7S- 1E	Mafic Intrusives
2- 7S- 2E	Mafic Intrusives
16- 7S- 2E	Mafic Intrusives
27-10S- 2E	Mafic Intrusives
27- 6S- 3E	Mafic Intrusives
19- 8S- 3E	Mafic Intrusives
29- 9S- 3E	Mafic Intrusives
33- 9S- 3E	Mafic Intrusives
19-10S- 3E	Mafic Intrusives

Cloud County:

16- 8S- 3W	Arkosic Sandstone
31- 8S- 2W	Mafic Intrusives

Cowley County:

25-30S- 4E	Mesozonal granite
31S- 4E(3 wells)	Mesozonal granite
14-35S- 4E	Mesozonal granite
2-30S- 6E	Mesozonal granite
26-31S- 6E	Mesozonal granite
9-35S- 6E	Mesozonal granite
18-33S- 7E	Epizonal granite
13-35S- 7E	Rhyolitic-Dacitic Volcanics
14-34S- 8E	Rhyolitic-Dacitic Volcanics

Crawford County:

20-28S-25E	Epizonal granite

Decature County:

22- 1S-31W	Mesozonal granite
1- 2S-30W	Mesozonal granite
6- 2S-30W	Mesozonal granite
4- 3S-30W	Mesozonal granite
36- 3S-30W	Mesozonal granite
36- 1S-29W(4 wells)	Mesozonal granite
36- 1S-28W(14 wells)	Mesozonal granite
36- 2S-29W(4 wells)	Mesozonal granite
36- 2S-28W(7 wells)	Mesozonal granite

Decatur County (continued)

36- 3S-29W(3 wells)	Mesozonal granite
27- 3S-28W	Mesozonal granite
28- 3S-28W	Mesozonal granite
4S-28W(4 wells)	Mesozonal granite
11- 5S-28W	Mesozonal granite
34- 5S-28W	Mesozonal granite
34- 1S-27W(16 wells)	Mesozonal granite
34- 2S-27W(11 wells)	Mesozonal granite
34- 3S-27W(3 wells)	Mesozonal granite
6- 5S-27W	Mesozonal granite

Dickinson County:

12-14S- 1W	Mafic Intrusives
3-16S- 1W	Mafic Intrusives
13-13S- 1E	Arkosic Sandstone
3-12S- 2E	Arkosic Sandstone
35-14S- 3E	Mesozonal granite

Douglas County:

6-14S-17E	Mesozonal granite
3-14S-20E	Quartzite

Edwards County:

2-24S-16W	Rhyolitic-Dacitic Volcanics
9-24S-16W	Rhyolitic-Dacitic Volcanics

Elk County:

15-30S-10E	Epizonal granite
33-31S-13E	Rhyolitic-Dacitic Volcanics

Ellis County:

12S-21W(3 wells)	Mesozonal granite
13S-21W(3 wells)	Mesozonal granite
14S-21W(11 wells)	Mesozonal granite
15S-21W(6 wells)	Mesozonal granite
11S-20W(5 wells)	Mesozonal granite
12S-20W(2 wells)	Mesozonal granite
13S-20W(2 wells)	Mesozonal granite
14S-20W(7 wells)	Mesozonal granite
15S-20W(6 wells)	Mesozonal granite
11S-19W(6 wells)	Mesozonal granite
12S-19W(3 wells)	Mesozonal granite
15S-19W(4 wells)	Mesozonal granite
11S-18W(11 wells)	Mesozonal granite
12S-18W(2 wells)	Mesozonal granite
13S-18W(5 wells)	Mesozonal granite
14S-18W(3 wells)	Mesozonal granite
30-15S-18W	Mesozonal granite

Ellsworth County:

8-14S-11W	Mesozonal granite
30-14S-11W	Mesozonal granite
27-14S-11W	Akrosic sandstone
27-16S-11W(5 wells)	Mesozonal granite
16S-11W(3 wells)	Arkosic sandstone
17S-11W(6 wells)	Quartzite
17S-11W(3 wells)	Mesozonal granite
1-17S-11W	Arkosic sandstone
14-15S-10W	Arkosic sandstone
34-15S-10W	Arkosic sandstone
23-16S-10W	Arkosic sandstone
17S-10W(6 wells)	Arkosic sandstone
29-15S- 9W	Arkosic sandstone
16S- 9W(4 wells)	Arkosic sandstone
17S- 9W(5 wells	Arkosic sandstone

Geary County:

17-11S- 4E	Arkosic sandstone

Gove County:

36-13S-31W	Mesozonal granite

Graham County:

16-10S-24W	Mesozonal granite
14- 9S-23W	Mesozonal granite
9S-22W(6 wells)	Mesozonal granite
10S-22W(3 wells)	Mesozonal granite

Greenwood County:

2-26W- 8E	Mesozonal granite
36-27S- 8E	Mesozonal granite
16,22-23S- 9E	Mesozonal granite
35-25S- 9E	Quartzite
18-28S- 9E	Mesozonal granite
12,20-22S-10E	Mesozonal granite
4-24S-10E	Quartzite
21-23S-11E	Mesozonal granite
1-25S-12E	Epizonal granite
25-26S-12E	Epizonal granite

Harvey County:

8,17-22S- 3W	Arkosic sandstone
16-23S- 2W	Arkosic sandstone
5-22S- 1W	Arkosic sandstone

Hodgeman County:

21S-22W(4 wells)	Rhyolitic-Dacitic Volcanics

Hodgeman County:

13-21S-24W	Rhyolitic-Dacitic Volcanics
14-21S-24W	Rhyolitic-Dacitic Volcanics
3-24S-24W	Rhyolitic-Dacitic Volcanics
14-23S-23W	Rhyolitic-Dacitic Volcanics

Jackson County:

1- 6S-11E	Mesozonal granite
12- 9S-11E	Mesozonal granite
6S-12E(3 wells)	Mesozonal granite
32- 7S-12E	Mesozonal granite
30- 8S-12E	Mesozonal granite
20- 6S-13E	Mesozonal granite

Jefferson County:

13- 9S-18E	Mesozonal granite

Johnson County:

12-14S-21E	Mesozonal granite

Kearny County:

15-21S-38W	Epizonal granite

Kingman County:

20-27S-10W	Mesozonal granite
15-30S- 7W	Rhyolitic-Dacitic Volcanics

Labette County:

13-32S-17E	Epizonal granite
5-31S-19E	Eipzonal granite
1-35S-19E	Mafic intrusives
17-31S-21E	Epizonal granite

Leavenworth County:

25- 8S-19E	Mesozonal granite

Logan County:

9-13S-38W	Rhyolite-Dacite
13-15S-34W	Epizonal granite

Lyon County:

32-15S- 9E	Quartzite
6-16S- 9E	Quartzite
21-16S- 9E	Quartzite

Lyon County (continued)

9-16S-10E	Quartzite
16-16S-10E	Quartzite
2-18S-11E	Mesozonal granite
24-18S-11E	Mesozonal granite
12-19S- 9E	Mesozonal granite
24-19S-10E	Mesozonal granite
15-18S-12E	Mesozonal granite

Marion County:

23-21S- 1E	Mesozonal granite
22,28-19S- 2E	Mesozonal granite
24-20S- 3E	Mesozonal granite
29-21S- 3E	Mesozonal granite
21S- 4E(4 wells)	Mesozonal granite
22S- 4E(4 wells)	Mesozonal granite
19S- 5E(3 wells)	Mesozonal granite
17,21-21S- 5E	Mesozonal granite
15-22S- 5E	Mesozonal granite

Marshall County:

20- 1S- 5E	Mesozonal granite
22- 5S- 5E	Arkosic sandstone
36- 1S- 6E	Arkosic sandstone
22- 3S- 6E	Arkosic sandstone
4S- 6E(3 wells)	Arkosic sandstone
5S- 6E(4 wells)	Arkosic sandstone
11- 1S- 7E	Mesozonal granite
16- 2S- 7E	Mesozonal granite
34- 2S- 7E	Arkosic sandstone
24- 3S- 7E	Arkosic sandstone
4S- 7E(5 wells)	Arkosic sandstone
19- 1S- 8E	Mesozonal granite
2S- 8E(5 wells)	Mesozonal granite
6- 3S- 8E	Mesozonal granite
5- 3S- 8E	Mesozonal granite
4S- 8E(4 wells)	Mesozonal granite
5S- 8E(4 wells)	Mesozonal granite
29- 1S- 9E	Mesozonal granite
32- 1S- 9E	Mesozonal granite
5- 3S- 9E	Mesozonal granite
15- 3S- 9e	Mesozonal granite
9- 4S- 9E	Mesozonal granite
15- 4S- 9E	Mesozonal granite

McPherson County:

9-17S- 3W	Mafic Intrusives
33-20S- 3W	Arkosic sandstone
21S- 3W(3 wells)	Arkosic sandstone
1,31-17S- 1W	Mafic Intrusives
12-19S- 1W	Arkosic sandstone

Miami County:

16-16S-22E	Mesozonal granite

Mitchell County:

21- 6S- 7W	Quartzite
34- 6S- 7W	Quartzite

Montgomery County:

11,24-34S-13E	Rhyolitic-Dacitic Volcanics
12-33S-14E	Rhyolitic-Dacitic Volcanics
7-33S-15E	Rhyolitic-Dacitic Volcanics
7,14-32S-16E	Rhyolitic-Dacitic Volcanics
4-35S-15E	Episozal grnaite
12,27-31S-16E	Episozal granite
5,12-33S-16E	Rhyolitic-Dacitic Volcanics
3-33S-17E	Rhyolitic-Dacitic Volcanics
15-34S-17E	Rhyolitic-Dacitic Volcanics

Morris County:

24-16S- 4E	Mesozonal granite
1-17S- 5E	Mesozonal granite
12-17S- 5E	Mesozonal granite
24-15S- 6E	Mesozonal granite
16S- 6E(3 wells)	Mesozonal granite
17S- 6E(5 wells)	Mesozonal granite
3-14S- 7E	Mesozonal granite
4-14S- 7E	Mesozonal granite
17-15S- 7E	Mesozonal granite
33-16S- 8E	Mesozonal granite
14-16S- 8E	Quartzite

Nemaha County:

21- 1S-10E	Mesozonal granite
29- 2S-10E	Mesozonal granite
18- 3S-10E	Mesozonal granite
18- 5S-10E	Mesozonal granite
5- 2S-11E	Mesozonal granite
28- 2S-11E	Mesozonal granite
21- 2S-12E	Mesozonal granite
25- 3S-12E	Mesozonal granite
26- 3S-12E	Mesozonal granite
27- 4S-12E	Mesozonal granite
23- 5S-12E	Mesozonal granite
6- 1S-13E	Mesozonal granite
2S-13E(4 wells)	Mesozonal granite

Neosho County:

22-27S-18E	Epizonal granite
34-30S-18E	Epizonal granite
30-28S-21E	Epizonal granite

Norton County:

1S-26W(10 wells)	Mesozonal granite
1S-25W(8 wells)	Mesozonal granite
2S-26W(8 wells)	Mesozonal granite
2S-25W(12 wells)	Mesozonal granite
3S-26W(12 wells)	Mesozonal granite
11- 4S-26W	Mesozonal granite
3S-25W(12 wells)	Mesozonal granite
4S-25W(6 wells)	Mesozonal granite
1S-24W(7 wells)	Mesozonal granite
1S-23W(8 wells)	Mesozonal granite
2S-24W(7 wells)	Mesozonal granite
2S-23W(6 wells)	Mesozonal granite
3S-24W(13 wells)	Mesozonal granite
4S-24W(9 wells)	Mesozonal granite
3S-23W(4 wells)	Mesozonal granite
4S-23W(8 wells)	Mesozonal granite
5S-23W(10 wells)	Mesozonal granite
5- 4S-22W	Mesozonal granite
11- 4S-22W	Mesozonal granite
5S-22W(8 wells)	Mesozonal granite

Osage County:

23-14S-13E	Mesozonal granite
14-16S-14E	Mesozonal granite
4-15S-15E	Mesozonal granite

Osborne County:

23-10S-16W	Mesozonal granite

Ottawa County:

7-10S- 3W	Akrosic sandstone

Pawnee County:

20S-20W(3 wells)	Rhyolitic-Dacitic Volcanics
20S-19W(3 wells)	Rhyolitic-Dacitic Volcanics
13-21S-18W	Mesozonal granite
21S-17W(3 wells)	Mesozonal granite
33-21S-16W	Mesozonal granite
34-21S-16W	Mesozonal granite
2-21S-16W	Rhyolitic-Dacitic Volcanics
14-21S-16W	Rhyolitic-Dacitic Volcanics
1-21S-15W	Rhyolitic-Dacitic Volcanics
6-21S-15W	Rhyolitic-Dacitic Volcanics
4-22S-20W	Rhyolitic-Dacitic Volcanics
30-23S-15W	Rhyolitic-Dacitic Volcanics
32-23S-15W	Rhyolitic-Dacitic Volcanics

Phillips County:

33- 1S-21W	Mesozonal granite
3S-21W(3 wells)	Mesozonal granite
4S-21W(3 wells)	Mesozonal granite
5S-21W(9 wells)	Mesozonal granite
21- 1S-20W	Quartzite
19- 2S-20W	Mesozonal granite
34- 2S-20W	Quartzite
36- 2S-20W	Quartzite
3S-20W	Mesozonal granite
4S-20W	Mesozonal granite
18- 4S-20W	Mesozonal granite
31- 4S-19W	Mesozonal granite
20- 4S-19W	Quartzite
29- 4S-19W	Quartzite
13- 5S-19W	Mesozonal granite

Pottawatomie County:

11- 7S- 6E	Mesozonal granite
1- 8X- 6E	Mesozonal granite
24- 8S- 6E	Mesozonal granite
6S- 7E(3 wells)	Mesozonal granite
8- 7S- 7E	Mesozonal granite
35- 8S- 7E	Mesozonal granite
9S- 7E(8 wells)	Mesozonal granite
6S- 8E(4 wells)	Mesozonal granite
7S- 8E(3 wells)	Mesozonal granite
6- 8S- 8E	Mesozonal granite
29- 8S- 8E	Mesozonal granite
9S- 8E(4 wells)	Mesozonal granite
2-10S- 8E	Mesozonal granite
8- 6S- 9E	Mesozonal granite
7S- 9E(7 wells)	Mesozonal granite
8S- 9E(7 wells)	Mesozonal granite
9S- 9E(5 wells)	Mesozonal granite
6-10S- 9E	Mesozonal granite
27- 6S-10E	Mesozonal granite
7S-10E(3 wells)	Mesozonal granite
8S-10E(3 wells)	Mesozonal granite
5- 9S-10E	Mesozonal granite
7S-11E(3 wells)	Mesozonal granite
8S-11E(4 wells)	Mesozonal granite
7- 9S-11E	Mesozonal granite

Pratt County:

25-26S-13W	Rhyolitic-Dacitic Volcanics
33-26S-13W	Rhyolitic-Dacitic Volcanics
22-28S-13W	Mesozonal granite

Rawlins County:

32- 4S-36W	Mesozonal granite
16- 2S-35W	Rhyolitic-Dacitic Volcanics
1S-35W(8 wells)	Quartzite
1S-34W(3 wells)	Quartzite

Reno County:

11,14-23S- 4W	Mesozonal granite
23,26-23S- 4W	Arkosic sandstone
24S- 4W	Arkosic sandstone

Rice County:

2-18S-10W	Mesozonal granite
18S-10W(18 wells)	Quartzite
19S-10W(15 wells)	Quartzite
12-19S-10W	Rhyolitic-Dacitic Volcanics
6-20S-10W	Rhyolitic-Dacitic Volcanics
20S-10W(6 wells)	Quartzite
17-18S- 9W	Mesozonal granite
28-18S- 9W	Mesozonal granite
19S- 9W(5 wells)	Quartzite
19S- 9W(5 wells)	Rhyolitic-Dacitic Volcanics
20S- 9W(5 wells)	Quartzite
18S- 8W(6 wells)	Arkosic sandstone
35-19S- 8W	Arkosic sandstone
18S- 7W(3 wells)	Arkosic sandstone
1-19S- 7W	Arkosic sandstone

Riley County:

25- 6S- 4E	Mafic Intrusives
28- 6S- 4E	Mafic Intrusives
2- 7S- 4E	Mafic Intrusives
3- 7S- 4E	Mafic Intrusives
24- 8S- 3E	Arkosic sandstone
11- 9S- 3E	Mafic Intrusives
14- 9S- 3E	Mafic Intrusives
8- 6S- 5E	Arkosic sandstone
16- 8S- 5E	Arkosic sandstone
16- 9S- 6E	Mesozonal granite
26-10S- 5E	Mesozonal granite
10S- 6E(3 wells)	Mesozonal granite
3-11S- 6E	Mesozonal granite
15-10S- 7E	Mesozonal granite
36-10S- 7E	Mesozonal granite
11S- 7E(4 wells)	Mesozonal granite
10S- 8E(3 wells)	Mesozonal granite
11S- 8E(7 wells)	Mesozonal granite

Rooks County:

6S-21W(7 wells)	Mesozonal granite
18- 7S-21W	Mesozonal granite
6- 8S-21W	Mesozonal granite
18- 9S-21W	Mesozonal granite
27- 9S-21W	Mesozonal granite

Rooks County (continued)

10S-21W	Mesozonal granite
6S-20W(7 wells)	Mesozonal granite
7S-20W(2 wells)	Mesozonal granite
8S-20W(3 wells)	Mesozonal granite
9S-20W(7 wells)	Mesozonal granite
10S-20W(2 wells)	Mesozonal granite
9S-19W(4 wells)	Mesozonal granite
6S-18W(2 wells)	Mesozonal granite
26- 7S-18W	Mesozonal granite
8S-18W(2 wells)	Mesozonal granite
9S-18W(2 wells)	Mesozonal granite

Rush County:

16S-20W(3 wells)	Mesozonal granite
16S-19W(3 wells)	Mesozonal granite
16S-18W(10 wells)	Mesozonal granite
16S-17W(6 wells)	Mesozonal granite
5-16S-17W	Quartzite
5-16S-16W	Mesozonal granite
17S-19W(3 wells)	Mesozonal granite
17S-18W(10 wells)	Mesozonal granite
17S-17W(13 wells)	Mesozonal granite
23-17S-17W	Quartzite
25-17S-17W	Quartzite
17S-16W(4 wells)	Quartzite
17S-16W(6 wells)	Mesozonal granite
21-18S-18W	Mesozonal granite
18S-17W(8 wells)	Mesozonal granite
18S-17W(3 wells)	Rhyolitic-Dacitic Volcanics
18S-16W(7 wells)	Rhyolitic-Dacitic Volcanics
18S-16W(14 wells)	Mesozonal granite
36-18S-16W	Quartzite
19S-16W(4 wells)	Mesozonal granite

Russell County:

11S-16W(3 wells)	Mesozonal granite
12S-16W(9 wells)	Mesozonal granite
13S-16W(4 wells)	Mesozonal granite
14S-16W(17 wells)	Mesozonal granite
13S-15W(6 wells)	Mesozonal granite
14S-15W(20 wells)	Mesozonal granite
14S-15W(8 wells)	Quartzite
15S-15W(8 wells)	Mesozonal granite
14S-14W(9 wells)	Mesozonal granite
15S-14W(10 wells)	Mesozonal granite
5-15S-14W	Quartzite
14S-13W(4 wells)	Mesozonal granite
15S-13W(6 wells)	Mesozonal granite
15S-13W(7 wells)	Quartzite

Russell County (continued)

15S-12W(3 wells)	Mesozonal granite
33-15S-12W	Quartzite

Saline County:

7-16S- 4W	Mafic Intrusives
6-15S- 2W	Mafic Intrusives

Sedgwick County:

1,12-26S- 1W	Quartzite
1-27S- 1W	Mesozonal granite
19,28-28S- 1W	Mesozonal granite
15,17-25S- 1E	Quartzite
34-26S- 1E	Mesozonal granite
29-28S- 1E	Mesozonal granite
26S- 2E(3 wells)	Mesozonal granite
11-27S- 2E	Mesozonal granite
5-29S- 2E	Mesozonal granite

Shawnee County:

14-11S-15E	Mesozonal granite
12-12S-15E	Mesozonal granite

Sheridan County:

2- 6S-28W	Quartzite
11- 6S-28W	Quartzite
24- 6S-27W	Mesozonal granite

Sherman County:

7-10S-40W	Mesozonal granite
10-10S-40W	Mesozonal granite

Stafford County:

21S-14W(3 wells)	Rhyolitic-Dacitic Volcanics
21S-12W(3 wells)	Rhyolitic-Dacitic Volcanics
1-22S-14W	Rhyolitic-Dacitic Volcanics
1-22S-12W	Rhyolitic-Dacitic Volcanics
3-22S-12W	Rhyolitic-Dacitic Volcanics
10-24S-15W	Rhyolitic-Dacitic Volcanics
24S-14W(3 wells)	Rhyolitic-Dacitic Volcanics
24S-13W(2 wells)	Rhyolitic-Dacitic Volcanics
24S-12W(2 wells)	Rhyolitic-Dacitic Volcanics
36-25S-14W	Rhyolitic-Dacitic Volcanics
12-25S-13W	Rhyolitic-Dacitic Volcanics
13-25S-13W	Rhyolitic-Dacitic Volcanics

Stevens County:

12-31S-38W	Rhyolitic-Dacitic Volcanics
13-34S-37W	Epizonal granite

Sumner County:

22-34S- 3W	Mesozonal granite
3-35S- 3W	Mesozonal granite
16-35S- 3W	Mesozonal granite
35S- 2W(3 wells)	Mesozonal granite
10-30S- 1W	Mesozonal granite
36-31S- 2E	Mesozonal granite
32S- 2E(3 wells)	Mesozonal granite
17-35S- 2E	Mesozonal granite

Trego County:

19-14S-25W	Quartzite
12S-23W(2 wells)	Mesozonal granite
11S-22W(2 wells)	Mesozonal granite
12S-22W(3 wells)	Mesozonal granite
13S-22W(4 wells)	Mesozonal granite
1-14S-22W	Mesozonal granite

Wabaunsee County:

1-12S- 7E	Mesozonal granite
26-10S- 8E	Mesozonal granite
11S- 8E(3 wells)	Mesozonal granite
2-12S- 8E	Mesozonal granite
10S- 9E(4 wells)	Mesozonal granite
11S- 9E(3 wells)	Mesozonal granite
12S- 9E(3 wells)	Mesozonal granite
3-14S- 9E	Mesozonal granite
10S-10E(4 wells)	Mesozonal granite
35-11S-10E	Mesozonal granite
12S-10E(3 wells)	Mesozonal granite
16-13S-11E	Mesozonal granite
34-13S-11E	Mesozonal granite

Wallace County:

18-13S-43W	Quartzite
28-11S-40W	Quartzite
17-14S-39W	Mesozonal granite

Washington County:

1- 1S- 1E	Mesozonal granite
15- 2S- 1W	Arkosic sandstone
26- 4S- 1W	Mafic Intrusives
2- 5S- 1W	Mafic Intrusives
9- 3S- 2E	Mafic Intrusives
14- 5S- 2E	Arkosic sandstone
3- 3S- 3E	Arkosic sandstone

Wilson County:

36-28S-14E	Rhyolitic-Dacitic Volcanics
13-28S-15E	Epizonal granite
10-29S-15E	Rhyolitic-Dacitic Volcanics
16-30S-15E	Epizonal granite
26-27S-16E	Epizonal granite
19-30S-16E	Epizonal granite
3-28S-17E	Epizonal granite
21-30S-17E	Epizonal granite

Woodson County:

26-25S-14E	Epizonal granite
25S-15E(3 wells)	Epizonal granite
29-25S-16E	Epizonal granite
8-24S-17E	Epizonal granite
20-26S-17E	Epizonal granite

Wyandotte County:

15-11S-24E	Mesozonal granite

KENTUCKY

Boone County:

Location	Rock Type
9-EE-5E	Arkose

Boyde County:

22- W-82	Anorthosite
11- V-81	Anorthosite
25- W-83	Anorthosite

Breathitt County:

13- M-75	Syenite(?) or hornblende gneiss

Campbell County:

25-DD-62	Basalt

Carter County:

14- V-81	Rhyolite or granite porphyry
22- U-79	Arkose(?)
23- U-79	Sandstone(?)
3- V-77	Microgranite
12- V-77	Quartz Diorite

Clark County:

16- S-65	Granite gneiss
9- Q-64	Granite

Elliot County:

23- T-76	Granite

Garrad County:

8- O-59	Metarhyolite

Greenup County:

7- Z-78	Quartz- diorite gneiss

Jessamine County:

6- P-60	Basalt

Jefferson County:

10- U-44	Olivine/Serpentinite

Johnson County:

7- P-82	Biotite schist

Lawrence County:

6- U-82	Granite

Leslie County:

8- I-73	Granite

Lewis County:

13- Y-76	Granofels
19- W-75	Granite
13- Y-77	Amphibolite

Madison County:

11- P-61	Hornblende Schist

Mason County:

15- Y-71	Hornblende-Garnet Granite

Menifee County:

21- S-72	Granite
14- Q-72	Granite

Montgomery County:

8- R-67	Granite

Morgan County:

23- R-73	Biotite Schist
14- S-75	Granite

Nicholas County:

16- X-66	Altered rhyolite

Pike County:

8- L-75(?)	Granofels

Pulaski County:

14- H-59	Rhyolite
24- H-60	Granite

Rowan County:

19- U-72	Granite
4- T-75	Granite
21- T-74	Granite

Webster County:

23- N-74	Granite
5- M-22	Altered basalt and arkose

Wolfe County:

13- O-74	Diorite

MICHIGAN

Berrien County:

Location	Rock Type
10- 6S-17W	Two feldspar Biotite granite

Delta County:

42N-22W	?

Gratiot County:

8-10N- 2W	Basalt

Huron County:

26-15N-15E	Granite

Kalamazoo County:

14- 3S-11W	Altered biotite granite

Lenawee County:

28- 8S- 5E	White sandstone, granite

Livingston County:

11- 3N- 5E	Granitic gneiss

Monroe County:

29- 5S-10E	White sandstone, biotite granite
19- 7S- 7E	Granite
16- 7S- 6E	Altered quartz-mica schist

Ogemaw County:

21-22N- 2E	Quartzite and dolomite

Ottawa County:

30- 5N-15W	Granite
30- 5N-15W	Mt. Simon Sandstone

Presque Isle County:

20-34N- 5E	White Sandstone (Dresbach sandstone)
13-33N- 5E	Clear quartzitic sandstone

St. Clair County:

31- 4N-15E	Rhyolite, granitic gneiss, chlorite-biotite-hornblende schistose gneiss, biotite gneiss, diorite gneiss.
3- 2N-16E	Sedimentary rock, granite, biotite-quartz schist
26- 5N-16E	Sandstone with biotite
7- 5N-17E	Limestone

Sanilac County:

20-12N-15E	Biotite granite

Wastenaw County:

16- 1S- 7E	Sandstone, granitic gneiss (weathered)
12- 2S- 7E	Sandstone

Wayne County:

22- 4S-10E	Quartzitic sandstone, Granite orgranofels

MISSOURI

(exclusive of the counties bordering the St. Francois Mountains: Iron, Madison, Reynolds, Shannon, Washington)

Adair County:

Location	Rock Type
8-61N-15W	Biotite granite?

Atchison County:

33-64N-40W	Biotite granite

Audrain County:

6-50N-7W	Granofels and schist with granite dikes
6-50N-7W	Norite with granite dikes
33-51N-7W	Uralitized hypersthene gabbro

Barry County:

32-26N-27W	Rhyolite porphyry?
23-24N-26W	Rhyolite and andesite

Barton County:

29-32N-30W	Biotite granite
1-20N-33W	Biotite granite

Bates County:

11-38N-33W	Rhyolite and quartz syenite prophyry
14-38N-31W	Biotite-quartz-microcline gneiss
23-38N-31W	Cataclastic granite gneiss and schist
6-40N-31W	"Granite"
14-38N-29W	"Granite"

Bollinger County:

19-30N- 8E	Rhyolite breccia
26-32N- 8E	"Granite"

Boone County:

20-20N-12W	Metarhyolite

Camden County:

5-37N-16W	Biotite-quartz-microcline gneiss

Carter County:

27-28N- 1W	"Granite"
3-27N- 2E	"Tuff"
33-28N- 1W	Not reported
15-27N- 1W	Leucogranite
12-27N- 1W	Porphyritic biotite
18-27N- 2W	Quartz-syenite porphyry
7-27N- 2W	Quartz-syenite porphyry
17-27N- 2W	Quartz-syenite porphyry

Cass County:

29-46N-32W	Biotite granite?
21-44N-29W	Not reported

Clark County:

5-65N- 6W	Diorite with granite and andesite dikes

Crawford County:

27-37N- 2W	Amphibole andesite
15-39N- 2W	Trachyte porphyry
20-40N- 2W	Rhyolite porphyry
14-35N- 2W	Kalialaskite with andesite dike
17-37N- 2W	Fine grained leucogranite
10-36N- 2W	Weathered granite
21-37N- 2W	Quartz microsyenite
16-36N- 2W	Syenite
33-36N- 2W	Granite
35-36N- 2W	Weathered granite
34-40N- 3W	Rhyolite porphyry, skarn, pegmatite
3-39N- 3W	Mineralized rhyolite prophyry
3-39N- 3W	Mineralized rhyolite prophyry
3-39N- 3W	Mineralized rhyolite porphyry
34-40N- 2W	Not reported
16-35N- 2W	Granite
9-35N- 2W	Granite
9-35N- 2W	Granite and syenite
9-35N- 2W	Leucogranite
17-35N- 2W	Granite
22-36N- 4W	"Monzonite"
2-39N- 2W	Weathered granite porphyry
34-40N- 2W	Weathered trachyte porphyry
34-40N- 2W	Weathered trachyte prophyry
34-40N- 2W	Weathered trachyte prophyry

Dallas County:

5-35N-18W	Cataclastic gneissic granite

Dent County:

3-34N- 6W	Diorite with syenite and andesite dikes

Dent County (continued)

17-34N- 2W	"Rhyolite"
9-34N- 2W	"Quartz monzonite"
25-35N- 4W	"Weathered granite"

Douglas County:

24-27N-15W	Biotite granodiorite

Franklin County:

31-45N- 3W	Weathered granite
13-44N- 2W	Hornblende granite
18-40N-2W	Rhyolite porphyry
18-40N- 2W	"Felsite"
18-41N- 2W	Hornblende granite

Gasconade County:

19-44N- 6W	Weathered granite
34-44N- 6W	Biotite granite, mylonitic
6-44N- 4W	Hornblende granite
6-45N- 4W	Hornblende quartz syenite
31-45N- 6W	Gneissic biotite granite

Greene County:

7-28N-22W	Granodiorite

Hickory County:

2-37N-21W	Biotite granite

Howard County:

22-51N-17W	Gneissic biotite granite
2-50N-17W	Biotite granite
13-50N-17W	Biotite granite
27-50N-17W	Biotite granite with quartz diabase dike
33-50N-17W	Sericite-hematite phyllite

Howell County:

28-26N- 8W	Biotite granodiorite
21-24N- 8W	Leucogranite

Jackson County:

17-50N-29W	Biotite granite
17-50N-30W	Biotite granite and hornblende diorite
7-48N-32W	Biotite granite gneiss
27-47N-31W	Metarhyolite
9-49N-29W	"Granite"
6-49N-29W	"Granite"

Jasper County:

3-28N-31W	Granite
36-28N-32W	Granite
10-28N-31W	Biotite granite

Jefferson County:

33-39N- 4E	Andesite porphyry
18-39N- 5E	Sheared trachyte prophyry
2-38N- 4E	Weathered trachyte?
27-39N- 4E	Porphyritic syenite
11-39N- 4#	Weathered trachyte?

Laclede County:

23-33N-15W	Biotite diorite with granite dikes
23-33N-15W	Gabbro and diorite
9-35N-14W	Granite gneiss
33-33N-13W	Granite gneiss, cataclastic
34-34N-15W	Diorite with granite dikes
20-33N-14W	Diorite with granite dikes
14-33N-15W	Granite-diorite gneiss and amphibolite
14-34N-16W	Biotite granite

McDonald County:

28-21N-31W	Granite porphyry
27-21N-34W	Micrographic granite prophyry
21-22N-34W	Micrographic granite porphyry
10-21N-34W	Micrographic granite porphyry

Macon County:

28-56N-15W	Granite?

Maries County:

30-40N- 8W	Biotite granite gneiss
32-39N- 9W	"Granite"

Miller County:

6-39N-14W	"Granite"

Morgan County:

27-40N-17W	Biotite-hornblende granite, sheared
24-42N-16W	Diorite
4-42N-19W	Adamellite over biotite diorite

Oregon County:

7-25N- 6W	Olivine gabbro and norite

Oregon County (continued)

7-25N- 6W	Uralite gabbro and norite
7-25N- 6W	Uralite gabbro and norite

Osage County:

20-45N- 7W	Granite porphyry
3-44N- 8W	Rhyolite porphyry and tuff

Pettis County:

22-45N-21W	Muscovite-quartz gneiss?
22-45N-21W	Muscovite-quartz gneiss
15-45N-21W	Muscovite-quartz gneiss
33-45N-21W	Biotite granite

Phelps County:

36-36N- 7W	
31-36N- 6W	Trachyte porphyry with albitite dikes
15-52N-36W	Granite
29-52N-34W	Not reported

Polk County:

25-33N-23W	Granite

Pulaski County:

31-37N-10W	Porphyroblastic biotite granite

Ralls County:

28-55N- 4W	Rhyolite
34-55N- 5W	Leucogranite

St. Charles County:

34-48N- 1E	Norite and diorite with granite dikes

St. Clair County:

21-38N-25W	"Granite"

St. Francois County:

36-38N- 4E	Granite
31-37N- 5E	Rhyolite porphyry
2-36N- 4E	Weathered igneous rock
4-36N- 4E	Rhyolite porphyry
14-36N- 4E	"Felsite"

St. Francois County:

15-36N- 4E	"Porphyry"
22-36N- 4E	"Felsite"
6-36N- 5E	"Rhyolite and granite"
6-36N- 5E	Not reported
25-36N- 5E	Granite
36-36N- 5E	Granite
36-36N- 5E	Porphyry
36N- 6E	Diabase and granite
15-35N- 4E	"Porphyry"
31-35N- 4E	Porphyry
2-35N- 5E	Granite
2-35N- 5E	Porphyry
2-35N- 5E	Granite
1-35N- 5E	Granite
17-35N- 5E	Granite
17-35N- 5E	"Granite"
17-35N- 5E	Weathered igneous rock
5-34N- 4E	Rhyolite
16-34N- 4E	Porphyry
10-34N- 6E	Granite

St. Louis County:

7-47N- 7E	Kalialaskite

Ste. Genevieve County:

15-35N- 7E	Diorite

Saline County:

8-48N-23W	Biotite-hornblende adamellite

Taney County:

15-24N-20W	Hornblende-biotite granite

Texas County:

25-32N-10W	Granite, cataclastic

Vernon County:

6-34N-29W	Biotite adamellite
31-37N-32W	Arkosic sandstone and shale
31-37N-32W	Arkose over syenite
12-35N-33W	"Granite"
36-35N-33W	"Quartzite?"
2-37N-30W	Rhyolite
8-36N-33W	Rhyolite prophyry

Wayne County:

10-27N- 3E	Granite
24-27N- 3E	Granite

Wayne County (continued)

26-27N- 4E	Granite
14-27N- 4E	Granite
24-27N- 3E	Granite
6-27N- 6E	Granite
17-28N- 4E	Not reported
2-30N- 7E	Rhyolite
3-27N- 3E	Rhyolite
6-30N- 5E	"Granite"
19-30N- 5E	"Granite"
28-30N- 5E	"Rhyolite"
15-30N- 5E	Diabase
11-29N- 5E	Porphyry
28-29N- 5E	Not reported
4-28N- 5E	Not reported
1-28N- 3E	"Basal conglomerate:

MONTANA

Blaine County:

3-28N-23E	Fine-grained equigranular granite

Carter County:

1- 8S-56E	Cataclastic granite gneiss
14- 7S-56E	Adamellite
29- 9S-58E	Granite
17- 6S-58E	Cataclastic granite gneiss
23- 9S-59E	Cataclastic grnaite gneiss

Chouteau County:

11-27N- 3E	Andesite breccia with prehnite

Custer County:

36- 2N-51E	Granite gneiss

Fallon County:

19- 4N-62E	Epidote-biotite-gneiss

Garfield County:

25-16N-38E	Quartzite

Hill County:

28-34N- 9E	Gabbro

Rosebud County:

9-10N-39E	Muscovite schist

Sheridan County:

	Foliated leucoadamellite

Toole County:

21-34N- 1W	Granodiorite gneiss

Valley County:

26-30N-36E	Granite gneiss

EASTERN NEW MEXICO

Chaves County:

Location	Rock Type
18- 4S-27E	Phyllite
7,14- 5S-26E	Rhyolite
25- 5S-24E	Sheared rhyolite
18- 6S-28E	Rhyolite
11- 6S-27E	Rhyolite
33- 6S-27E	Granite
12- 6S-30E	Rhyolite
7- 7S-31E	Granite
25- 7S-29E	Granite
20- 7S-27E	Granite
5- 8S-26E	Diabase, granite
14- 8S-26E	Granodiorite
21- 8S-26E	Granite
6- 8S-29E	Micrographic granite
5- 8S-30E	Granite
23- 8S-32E	Diabase
22- 8S-32E	Rhyolite
1- 9S-28E	Micrographic granite
19- 9S-28E	Diorite
31- 9S-28E	Granite
10- 9S-26E	Granite
13-10S-25E	Granite
20-10S-26E	Diabase
27-10S-26E	Granite
16-10S-27E	Granite gneiss
31-10S-27E	Granite gneiss
19-10S-28E	Granite
26-11S-26E	Granite
24-11S-27E	Granite
33-11S-27E	Granite
34-11S-31E	Micrographic granite
6-12W-29E	Granite gneiss
10-12S-27E	Granite gneiss(?)
20-12S-26E	Granite
22-12S-25E	Granite
6-13S-31E	Micrographic granite
32-13S-29E	Granite gneiss
35-14S-17E	Quartzite, diabase
23-14S-22E	Diabase, granite
2-14S-26E	Mica schist
27-14S-26E	Granite
35-14S-27E	Granite
22-14S-28E	Mica Schist
30-15S-30E	Rhyolite
21-15S-29E	Granodiorite
23-15S-29E	Granite-microgranite

Chaves County (continued)

23-15S-25E	Amphibolite
30-15S-22E	Granite gneiss
3-16S-16E	Microgranite porphyry
17-16S-18E	Rhyolite
24-16S-20E	Granite gneiss, diabase
31-17S-20E	Arkose, sandstone
22-17S-18E	Granite gneiss
10-18S-16E	Marble
19-19S-17E	Metaandesite
21-19S-17E	Metaandesite

Colfax County:

26-31N-21E	Granofels
24-30N-22E	Granite gneiss
10-29N-24E	Granite
17-29N-22E	Diabase, grewacke
11-28N-22E	Micrographic granite porphyry
35-27N-24E	Granite

Curry County:

31- 8N-37E	Granite(?) or Arkose
18- 5N-37E	Rhyolitic ignimbrite
10- 5N-32E	Rhyolitic ignimbrite
16- 4N-31E	Rhyolitic, Arkose
8- 3N-31E	Rhyolitic, Arkose
13- 3N-32E	Rhyolitic, Arkose
2- 3N-32E	Gneissic granite

De Baca County:

22- 5N-26E	Feldspathic quartzite
31- 3N-28E	Granite gneiss
17- 2N-25E	Pyroxene micrographic granite
20- 2N-22E	Altered diabase
13- 1N-22E	Basalt
2- 1S-20E	Diabase
23- 1S-25E	Feldspathic quartzite
12- 1S-27E	Granite
20- 2S-22E	Sandstone, argillite
6- 3S-22E	Diabase, metasediment
23- 3S-24E	Diabase

Eddy County:

2-16S-25E	Biotite Schist
12-16S-27E	Diabase
24-16S-30E	Microgranite
29-17S-31E	Metarhyolite
24-18S-23E	Granite (gneiss?)
10-19S-23E	Granite gneiss

Eddy County (continued)

23-20S-31E	Granite
28-21S-26E	Diabase
16-21S-22E	Diabase, Quartzite
23-23S-22E	Biotite granodiorite
35-23S-22E	Granite
2-25S-31E	Granite gneiss, diabase

Guadalupe County:

24-11N-18E	Granodiorite gneiss
22-11N-21E	Gneissic granite
14-10N-24E	Quartzite
21-10N-23E	Phyllite
32-10N-23E	Quartzofeldspathic schist
22-10N-22E	Quartzofeldspathic schist
33-10N-12E	Granite gneiss
27- 9N-19E	Metarhyolite
16- 8N-24E	Micrographic granite porphyry
20- 8N-22E	Sheared quartzite
2- 8N-23E	Diabase
3- 8N-19E	Greenschist, metagreywacke
5- 8N-19E	Greenschist, metagreywacke
3- 8N-18E	Greenschist
15- 7N-22E	Diabase
24- 5N-16E	Phyllite, greywacke

Harding County:

13-22N-28E	Granite
18-20N-30E	Granite
36-21N-32E	Granite
4-19N-32E	Granite
36-19N-30E	Granite
21-19N-30E	Granite
16-19N-30E	Granite
18-19N-30E	Diabase
27-16N-33E	Granite

Lea County:

34-10S-36E	Diabase
24-12S-36E	Rhyolite
12-12S-33E	Rhyolite
26-12S-33E	Micrographic granite porphyry
3-15S-33E	Rhyolite
14-15S-37E	Rhyolite
23-17S-33E	Granite, Arkose
26-17S-34E	Granite
6-17S-37E	Granite
2-19S-33E	Metarhyolite
35-19S-35E	Granite
4-24S-34E	Metarhyolite
32-25S-33E	Diabase

Lincoln County:

23- 2S-15E	Granodionte
10- 5S-16E	Granite gneiss, diorite
11- 9S-20E	Basalt
10-12S-18E	Meta-arkose
33- 6S- 9E	Diabase

Mora County:

14-23N-17E	Gneissic granite
2-20N-19E	Metarhyolite, metagreywacke
12-19N-21E	Gneissic granite

Otero County:

5-17S-12E	Quartzite, Diabase
22-21S-16E	Marble
18-21S-19E	Diabase
19-23S-18E	Diabase
28-24S-15E	Metaandesite(?)
36-25S-16E	Diabase, marble, micrographic granite
5-26S-16E	Diabase, Rhyolite

Quay County:

16-14N-32E	Granite
11-12N-32E	Granite porphyry, diabase
35-12N-34E	Muscovite schist, amphibolite schist
2-10N-27E	Diabase
25- 8N-30E	Rhyolite Tuff

Roosevelt County:

5- 2N-30E	Diabase, Arkose
15- 1S-35E	Quartz-Syenite
27- 2S-29E	Sheared granite gneiss
33- 3S-33E	Diabase
9- 4S-35E	Diabase
29- 4S-32E	Amphibolite
36- 4S-31E	Granite gneiss
26- 4S-30E	Sheared granite gneiss
7- 5S-30E	Sheared granite gneiss
31- 5S-33E	Granite gneiss
30- 5S-34E	Rhyolite
20- 6S-37E	Rhyolite
15- 6S-32E	Rhyolite
15- 7S-32E	Rhyolite
11- 7S-33E	Rhyolite
6- 7S-34E	Granodioritic gneiss
27- 7S-35E	Rhyolite
2- 7S-36E	Rhyolite
1- 7S-37E	Rhyolite
27- 7S-37E	Rhyolite
5,16- 8S-37E	Rhyolite

Roosevelt County (continued)

23- 8S-37E	micrographic granite
6,18- 8S-35E	Diabase

San Miguel County:

25-18N-26E	Altered granodiorite
25-17N-16E	Altered schist, granitic gneiss
28-17N-18E	Schist
34-17N-21E	Schist
2-16N-26E	Granitic gneiss
15-16N-17E	Banded granitic gneiss
1-15N-12E	Granodioritic gneiss
2-15N-18E	Sheared granite gneiss
36-16N-24E	Granite(gneiss?), diabase
34-15N-26E	Granitic gneiss
12-14N-27E	Granite
33-14N-15E	Schist
16-13N-14E	Granite gneiss
3-13N-15E	Granite gneiss
25-13N-26E	Rhyolite, Arkose
17-12N-30E	Granite (gneiss?)
14-12N-29E	Rhyolitic ignimbrite, Arkose, basalt
26-12N-23E	Diabase
14-12N-22E	Granite
29-12N-14E	Granite
22-11N-13E	Granite gneiss
14,15-11N-14E	Granite, Granite (gneiss?)
29-10N-12E	Granite gneiss

Santa Fe County:

14-14N-11E	Muscovite Schist
25-14N-11E	Granite
16-12N-10E	Granite
23-12N-11E	Granitic gneiss

Torrance County:

32- 9N- 8E	Phyllite
12- 7N- 7E	Metarhyolite
33- 7N- 7E	Metarhyolite
36- 7N- 7E	Metarhyolite
27- 7N- 9E	Schist
12- 6N- 6E	Metarhyolite
4- 6N- 7E	Biotite schist
23- 6N- 7E	Granitic gneiss, metarhyolite
19- 6N- 9E	Schist
21- 6N-10E	Arkose
30- 6N-11E	Sheared granite
1- 6N-13E	Argillite schist

Union County:

16-31N-36E	Granite
32-32N-31E	Granite,diabase
24-30N-36E	Granite
21-30N-34E	Granite
33-30N-29E	Granofels, granite
14-29N-36E	Granite
22-29N-32E	Granite
9-28N-35E	Diabase
3-28N-34E	Granite
22-25N-31E	Rhyolite
2-24N-36E	Rhyolite
14-24N-30E	Rhyolite
2-23N-33E	Granite
2-21N-34E	Granite
29-21N-36E	Granite

NEBRASKA

Adams County:

Location	Rock Type
35- 5N- 9W	Gneissic granodiorite
6- 7N-12W	Biotite adamellite

Antelope County:

Location	Rock Type
31-25N- 6W	Biotite gneiss

Arthur County:

Location	Rock Type
13-17N-37W	Basement not reached
35-17N-40W	Gneissic biotite adamellite
33-20N-36W	Gneissic biotite granite
30-20N-39W	Quartzite
35-20N-40W	Quartzite

Banner County:

Location	Rock Type
21-18N-55W	Chlorite granite
15-19N-53W	Biotite granite

Blaine County:

Location	Rock Type
29-21N-23W	Cataclastic granite
22-24N-21W	Chlorite-biotite granite
23-24N-23W	Gneissic adamellite

Boone County:

Location	Rock Type
23-22N- 7W	Muscovite biotite schist

Box Butte County:

Location	Rock Type
1-28N-48W	Cataclastic quartz diorite
19-27N-49W	Biotite hornblende gneiss

Buffalo County:

Location	Rock Type
9- 8N-18W	Gneissic quartz diorite
11- 9N-15W	Biotite hornblende schist
7- 9N-18W	Biotite gneiss quartzite
15- 9N-18W	Cataclastic biotite adamellite
20- 9N-18W	Biotite hornblende gneiss
3-10N-14W	Sericite schist
31-10N-18W	Granofels
8-11N-13W	Biotite adamellite
9-11N-18W	Hornblende schist
21-11N-18W	Chlorite-biotite gneiss and schist over altered granodiorite

Buffalo County (continued)

11-12N-13W	Quartz diorite
18-12N-17W	Chlorite granodiorite and hornblende gneiss
13-21N- 9E	Leucoadamellite

Butler County:

29-16N- 2E	Biotite granite(?)

Cass County:

28-10N-12E	Argillite
26-11N-12E	Arkosic quartzite and comglomerate
5-11N-13E	Quartz-collophane(?) sedimentary rock
8-11N-13E	Altered syenite

Chase County:

17- 5N-36W	Hornblende schist
27- 5N-38W	Gneissic quartz diorite
6- 5N-40W	Foliated biotite granite
21- 6N-36W	Biotite granite
9- 6N-37W	Biotite quartz diorite
12- 6N-37W	No crystalline rock seen
26- 7N-36W	Biotite granodiorite
15- 7N-37W	Schist and quartzite
5- 7N-39W	Biotite gneiss
10- 7N-41W	Gneissic biotite adamellite
15- 8N-36W	Gneissic quartz diorite
24- 8N-37W	Biotite granodiorite
14- 8N-40W	No samples
23- 8N-38W	Granofels
11- 8N-38W	Biotite Schist
1- 7N-41W	Rounded qtz + feldspar (basement?)

Chase County:

21- 8N-38W	Foliated biotite adamellite
24- 8N-38W	Foliated adamellite
15- 8N-39W	Biotite adamellite

Cherry County:

18-25N-29W	Quartzite over granofels
23-25N-35W	Graphic granite
34-26N-32W	Granofels
28-28N-30W	Biotite granite
11-29N-40W	Gneissic biotite-hornblende granite
12-29N-37W	Gneissic hornblende biotite granite and metadiabase
13-30N-39W	Muscovite biotite schist

Cherry County (continued)

25-30N-33W	Quartz-feldspar gneiss
23-31N-38W	Hornblende gneiss
1-31N-36W	Granofels
5-33N-27W	Muscovite-biotite over gneiss and biotite-muscovite over hornblende gneiss
12-33N-37W	Leucogranite
29-28N-34W	No sample
19-33N-40W	Granofels

Cheyenne County:

2-14N-48W	Biotite granite
7-14N-49W	Metarhyolite

Clay County:

28- 5N- 7W	Gneissic biotite quarts diorite

Colfax County:

7-17N- 3E	Hornblende schist

Custer County:

21-13N-19W	Quartzite
13-13N-20W	Quartzite
21-13N-20W	Quartzite
28-13N-23W	Leucoadamellite
18-13N-24W	Chlorite-biotite schist
9-14N-17W	No crystalline rocks seen
29-14N-22W	Altered granite(?)
4-14N-23W	Cuttings too small to identify rock
12-14N-25W	Gneissic biotite adamellite
27-15N-19W	Questionable if this is basement
30-14N-20W	Granofels
18-15N-24W	Actinolite schist
34-16N-21W	Biotite granite
27-17N-17W	Granite(?)
21-17N-23W	Chlorite hornblende gneiss
11-18N-17W	Chlorite biotite gneiss
11-19N-19W	Sericite chlorite gneiss
22-20N-25W	Cataclastic biotite adamellite

Dawes County:

13-29N-27W	Biotite hornblende
16-29N-49W	Chlorite granodiorite
23-30N-47W	Pegmatite(?)
14-30N-48W	Granite
2-30N-51W	Metadiabase
7-31N-47W	Muscovite granite
22-31N-49W	Biotite muscovite
28-31N-49W	Foliated granodiorite
5-31N-51W	No crystalline rocks seen
11-31N-51W	Metadiabase
17-31N-52W	Actinolite chlorite schist

Dawes County (continued)

19-32N-48W	Cataclastic quartz diorite
5-33N-50W	Granite
32-32N-50W	Chlorite schist
6-32N-51W	Biotite granodiorite
10-32N-52W	Altered muscovite granite
27-33N-47W	Biotite hornblende gneiss
16-33N-49W	Foliated adamellite
4-34N-47W	Foliated granite

Dawson County:

3- 9N-19W	Altered gneiss
10- 9N-19W	Hornblende schist
23- 9N-19W	Hornblende schist
26- 9N-20W	Hornblende gneiss
22- 9N-23W	Gneissic hornblende biotite granite granodiorite
36- 9N-24W	Biotite hornblende schist
25- 9N-25W	Hornblende schist
1-10N-19W	chlorite-biotite gneiss
14-10N-19W	Biotite schist
27-10N-21W	Cataclastic leucoadamellite
21-10N-22W	Granofels
29-10N-24W	Questionable whether this is basement
34-12N-21W	Granite or Granitic gneiss
29-12N-21W	No samples
26-11N-25W	Granofels
24-12N-20W	Quartzite
34-12N-21W	Hornblende biotite granodiorite
11-12N-22W	Quartzite
12-12N-25W	Hornblende quartz diorite
32-12N-25W	Layered gneiss and schist

Deuel County:

18-14N-42W	Biotite granite

Dodge County:

14-20N- 6E	Hornblende diorite, hornblende gneiss, and hornblende schist

Dougals County:

11-16N-12E	Altered basalt
4-14N-13E	Olivine basalt
25-16N- 9E	Arkosic sandstone

Dundy County:

10- 1N-36W	Gneissic biotite adamellite

Dundy County (continued)

10- 2N-36W	Biotite gneiss
8- 2N-37W	Meta silicic volcanic
20- 2N-37W	Clastic sedimentary rock
24- 2N-39W	Altered hornblende Schist (5340-50) Hornblende Schist (5354-63)
17- 2N-41W	Quartzite underlain by granofels
31- 3N-40W	Granite
29- 3N-40W	Biotite adamellite
1- 4N-41W	Biotite granodiorite
32- 4N-41W	Micaceous quartzite

Fillmore County:

22- 5N- 1W	Hornblende schist

Frontier County:

4- 5N-25W	Gneissic biotite hornblende granite, biotite granite, and quartzite
28- 5N-25W	Foliated biotite adamellite
33- 5N-25W	Foliated biotite leucoadamellite
13- 5N-26W	Granitic sand
18- 5N-26W	Gneissic biotite adamellite
22- 5N-26W	Hornblende biotite gneiss
36- 5N-26W	Biotite schist
1- 5N-27W	Granofels
25- 5N-27W	Leucoadamellite and gneissic granodiorite
36- 5N-27W	Granofels(?)
18- 5N-28W	Diopside-hornblende-biotite schist
23- 5N-28W	Granofels
3- 5N-29W	Hornblende biotite schist
5- 5N-29W	Hornblende gneiss
21- 5N-29W	Diopside-biotite-hornblende gneiss
28- 5N-29W	Granofels
32- 5N-29W	Biotite gneiss
3- 5N-30W	Granite(?) or arkose(?)
5- 5N-30W	Biotite-muscovite gneiss
7- 5N-30W	Granite(?) or arkose(?)
11- 5N-30W	Foliated(?) leucoadamellite
20- 5N-30W	Diopside-hornblende schist
21- 5N-30W	Gneissic adamellite
28- 5N-30W	Leucoadamellite
5- 6N-24W	Cataclastic biotite gneiss
17- 6N-25W	Granofels
34- 6N-25W	Granofels
4- 6N-26W	Cataclastic quartz-feldspar gneiss
14- 6N-26W	Foliated leucoadamellite
30- 6N-26W	Granite
9- 6N-27W	Biotite-hornblende schist
13- 6N-28W	Foliated muscovite biotite adamellite

Frontier County (continued)

20- 6N-28W	Muscovite gneiss
2- 6N-29W	Actinolitic anorthosite
27- 6N-29W	Biotite quartz diorite
2- 6N-30W	Gabbro
18- 6N-30W	Gabbro
20- 6N-30W	Biotite hornblende schist
22- 6N- 30W	Hornblende schist
26- 6N-30W	Biotite gneiss
28- 6N-30W	Granofels
33- 6N-30W	Gneissic muscovite biotite adamellite
13- 7N-25W	Biotite-hornblende schist
33- 7N-25W	Mylonite
29- 7N-26W	Mylonite
20- 7N-27W	Muscovite schist
3- 7N-28W	Quartz diorite
7- 7N-29W	Biotite hornblende granulite
15- 7N-29W	Anorthosite
23- 7N-30W	Anorthosite
32- 7N-30W	Anorthositic olivine gabbro
26- 8N-24W	Biotite hornblende schist
32- 8N-25W	Biotite gneiss(?)
13- 8N-26W	Biotite schist
36- 8N-26W	Quartz-feldspar gneiss
11- 8N-27W	Biotite schist
18- 8N-27W	Hornblende biotite schist
32- 8N-27W	Biotite-chlorite schist
13- 8N-28W	Mylonitic gneiss
14- 8N-29W	Foliated quartz diorite
7- 8N-30W	Foliated quartz diorite
11- 8N-30W	Chlorite actinolite schist

Furnas County:

21- 1N-21W	Muscovite-biotite schist
10- 1N-22W	Hornblende granite
28- 1N-22W	Granofels
8- 1N-23W	Granofels
9- 1N-23W	Granite(?)
28- 1N-23W	Hornblende biotite granodiorite
5- 1N-24W	Biotite adamellite
23- 1N-24W	Foliated biotite adamellite
29- 1N-24W	Biotite hornblende granite
31- 1N-24W	Biotite granite
9- 1N-25W	Biotite granite
14- 1N-25W	Hornblende biotite granite
15- 1N-25W	Hornblende biotite granite
19- 1N-25W	Biotite granite
24- 1N-25W	Biotite granite
27- 1N-25W	Biotite hornblende granite
29- 1N-25W	Biotite leucogranite
31- 1N-25W	Biotite adamellite
33- 1N-25W	Hornblende biotite granodiorite
34- 1N-25W	Biotite adamellite
7- 2N-21W	Hornblende biotite schist
18- 2N-21W	Biotite adamellite

Furnas County (continued)

28- 2N-21W	Gneissic biotite adamellite
33- 2N-21W	Metamorphic rock (?)
1- 2N-22W	Granofels
1- 2N-23W	Granofels
9- 2N-23W	Granofels
14- 2N-24W	Biotite hornblende adamellite
3- 2N-25W	Biotite adamellite
5- 2N-25W	Granite
9- 2N-25W	Granofels
15- 2N-25W	Biotite hornblende granite
16- 2N-25W	Biotite granite
17- 2N-25W	Hornblende granite
17- 2N-25W	Hornblende granite
17- 2N-25W	Hornblende granite
22- 2N-25W	Granite
31- 2N-25W	Biotite hornblende adamellite
30- 3N-22W	Biotite adamellite
14- 3N-23W	Biotite adamellite
6- 3N-24W	Granofels
10- 3N-24W	Granofels
7- 3N-25W	Hornblende biotite granite
11- 3N-25W	Biotite-clinopyroxene-hornblende granite
31- 3N-25W	Granofels
3- 4N-21W	Mylonite
11- 4N-21W	Cataclastic gneiss
14- 4N-21W	Cataclastic quartz diorite
25- 4N-21W	Cataclastic quartz diorite
1- 4N-22W	Biotite granite
9- 4N-22W	Cataclastic biotite granite
1- 4N-23W	Biotite granite
10- 4N-23W	Biotite granite
27- 4N-24W	Biotite granite
2- 4N-25W	Biotite leucoadamellite
6- 4N-25W	Hornblende-biotite schist
17- 4N-25W	Biotite adamellite
23- 4N-25W	Granite
34- 4N-25W	Granofels

Gage County:

9- 1N- 6E	Hornblende biotite granite
14- 1N- 6E	Chlorite granite
24- 1N- 6E	Chlorite adamellite
12- 1N- 8E	Schist & gneiss
3- 2N- 6E	Biotite granite
27- 2N- 7E	One feldspar hornblende granite
7- 2N- 8E	Granite
21- 3N- 5E	Foliated biotite adamellite
21- 3N- 5E	Chloritized biotite gneiss
27- 3N- 5E	Granitic mylonite
11- 3N- 7E	Granite(?)
12- 3N- 8E	Biotite hornblende granite
30- 3N- 8E	Granite
4- 4N- 7E	Quartz diorite(?)

Cage County (continued)

27- 5N- 6E	Biotite hornblende granite
14- 5N- 8E	Basalt

Garden County:

32-16N-43W	Metagabbro and gneiss
29-17N-43W	Cataclastic biotite gneiss
36-18N-42W	Granite(?)
25-18N-45W	Cataclastic biotite granite
33-19N-42W	Biotite adamellite
28-21N-41W	Granofels

Garfield County:

32-22N-15W	Hornblende schist
21-22N-16W	Altered biotite gneiss
5-23N-16W	Cataclastic granite

Gosper County:

5- 5N-21W	Biotite adamellite
14- 5N-21W	Amphibole-biotite gneiss
34- 5N-21W	Granofels
16- 5N-22W	Mylonite
34- 5N-22W	Cataclastic biotite chlorite granite
33- 5N-23W	Granitic rock (tiny, sparse)
31- 5N-23W	Chloritized biotite granite
17- 6N-23W	Biotite gneiss
30- 7N-21W	Hornblende biotite gneiss
22- 7N-22W	Biotite schist
8- 7N-23W	Altered cataclastic syenodiorite
33- 7N-23W	Cataclastic biotite adamellite
6- 8N-21W	Biotite hornblende gneiss
12-21N-37W	Leucogranite
9-21N-39W	Chlorite-muscovite-biotite schist

Grant County:

8-22N-36W	Cataclastic gneiss
5-22N-39W	Micrographic granite
1-23N-38W	Layered quartz feldspar gneiss and biotite hornblende schist
22-24N-38W	Biotite hornblende adamellite

Greely County:

33-19N-11W	Biotite quartz diorite

Hall County:

20-10N-12W	Biotite granite

Harlan County:

8- 1N-20W	Muscovite biotite adamellite
17- 2N-17W	Biotite hornblende monzonite
31- 2N-17W	Biotite schist and granofels
29- 3N-19W	Granofels

Hayes County:

1- 5N-31W	Gneissic biotite adamellite
11- 5N-31W	Leucogranite
12- 5N-31W	Muscovite-biotite gneiss
14- 5N-31W	Foliated leucoadamellite
21- 5N-31W	Granite(?)
24- 5N-31W	Biotite granodiorite
27- 5N-31W	Biotite adamellite
35- 5N-31W	Foliated hornblende biotite granite
13- 5N-32W	Muscovite biotite gneiss
16- 5N-32W	Biotite hornblende gneiss
15- 5N-34W	Norite
29- 5N-34W	Hornblende biotite gneiss
6- 6N-31W	Biotite hornblende schist
20- 6N-31W	Cataclastic gneiss
23- 6N-31W	Muscovite biotite schist
30- 6N-32W	Biotite granodiorite
36- 6N-32W	Gneissic muscovite biotite granodiorite
5- 6N-33W	Biotite granodiorite
21- 6N-33W	Granite(?)
23- 6N-35W	Biotite hornblende gneiss
20- 7N-31W	Hornblende anorthosite
25- 7N-31W	Anorthosite
13- 7N-32W	Leuco granite
18- 7N-32W	Precambrian(?) conglomerate
25- 7N-32W	Granite(?)
30- 7N-32W	Foliated biotite adamellite
31- 7N-32W	Gneissic muscovite biotite adamellite
8- 7N-33W	Foliated(?) leucoadamellite
21- 7N-33W	Gneissic biotite granite
20- 7N-34W	Biotite hornblende schist
25- 7N-34W	Muscovite-biotite granite
32- 7N-34W	Biotite granodiorite
3- 7N-35W	Foliated biotite adamellite
8- 8N-31W	Altered anorthosite
13- 8N-32W	Anorthosite
14- 8N-33W	Biotite granodiorite
27- 8N-33W	Leucogranite
10- 8N-34W	Cataclastic gneissic leucoadamellite
17- 8N-34W	Cataclastic gneissic adamellite
23- 8N-34W	Cataclastic gneissic granite
34- 8N-34W	Cataclastic biotite adamellite
2- 8N-35W	Biotite adamellite

Hitchcock County:

4- 1N-31W	Hornblende biotite granite
6- 1N-31W	Biotite granite
8- 1N-31W	Hornblende biotite granite
11- 1N-31W	Biotite granite
23- 1N-31W	Biotite hornblende granite
25- 1N-31W	Chloritized biotite granite
29- 1N-31W	Biotite hornblende granite
32- 1N-31W	Quartzite
8- 1N-32W	Gneissic biotite adamellite
21- 1N-32W	Quartzite
21- 1N-32W	Quartzite
23- 1N-32W	Sillimanite quartzite
26- 1N-32W	Quartzite
27- 1N-32W	Quartzite
27- 1N-32W	Granofels
28- 1N-32W	Quartzite
28- 1N-32W	Quartzite
29- 1N-32W	Quartzite over biotite schist
4- 1N-33W	Granite(?)
29- 1N-33W	Quartzite
31- 1N-33W	Biotite-hornblende schist
34- 1N-34W	Biotite gneiss
4- 2N-31W	Granite
10- 2N-31W	Granofels
12- 2N-31W	Granofels
20- 2N-31W	Hornblende biotite gneiss
15- 2N-32W	Biotite gneiss
35- 2N-32W	Foliated granite
16- 2N-33W	Granite
35- 2N-33W	Hornblende biotite gneiss
36- 3N-31W	Granofels
12- 3N-32W	Hornblende schist and foliated adamellite
18- 3N-33W	Foliated biotite granodiorite
19- 3N-34W	Muscovite biotite granodiorite
21- 3N-34W	Granite
16- 3N-35W	Foliated quartz diorite
12- 4N-31W	Foliated biotite granodiorite
18- 4N-31W	Foliated biotite granodiorite
16- 4N-32W	Biotite
23- 4N-33W	Foliated muscovite biotite adamellite
13- 4N-34W	Biotite hornblende schist
36- 4N-34W	Foliated leucoadamellite
21- 4N-35W	Biotite quartz diorite

Holt County:

9-25N-16W	Biotite hornblende gneiss
35-31N-15W	Biotite schist (V. sparse)
27-25N-16W	Biotite schist
3-30N-15W	Biotite schist (sparse)
15-27N-16W	Muscovite-biotite schist
23-28N-15W	Gneissic biotite granite
9-29N- 9W	Biotite gneiss
13-29N-13W	Gneissic biotite granite

Hooker County:

13-21N-33W	Biotite adamellite
27-22N-34W	Granite
5-23N-31W	Rhyolite
26-23N-33W	Granofels

Howard County:

25-13N-11W	Biotite hornblende gneiss
10-16N-12W	Biotite granite

Johnson County:

4- 4N-12E	Muscovite biotite granite
19- 5N- 9E	Muscovite biotite schist
28- 5N- 9E	Granite
8- 5N-12E	Gneissic biotite muscovite granite
16- 5N-12E	Foliated biotite muscovite adamellite
20- 5N-12E	Hornblende biotite gneiss
6- 6N-12E	Granite(?)

Kearney County:

28- 8N-13W	Hornblende biotite quartz diorite

Keith County:

11-12N-35W	Granofels over hornblende schist
12-12N-36W	Biotite adamellite
1-13N-35W	Biotite granite
15-13N-35W	Leucoadamellite
25-14N-35W	Biotite schist
26-14N-35W	Biotite schist
34-16N-36W	Altered biotite schist
35-15N-36W	Biotite granodiorite
22-15N-41W	Biotite granite
31-16N-37W	Hornblende schist overlain by granodiorite
15-16N-38W	Gneissic biotite granite

Keya Paha County:

19-34N-17W	No PE seen

Kimball County:

26-15N-56W	Metabasalt
15-16N-54W	Muscovite schist

Knox County:

24-32N- 7W	Sioux Formation

Lancaster County:

14- 8N- 6E	Clastic sedimentary rock

Lancaster County (continued)

19- 9N- 5E	Altered basalt
36- 9N- 5E	Arkosic sandstone
27- 9N- 6E	Ophitic basalt
35- 9N- 8E	Altered basalt
26-10N- 7E	Ophitic basalt

Lincoln County:

24- 9N-26W	Biotite actinolite schist and granitic gneiss
8- 9N-27W	Actinolite schist
34-13N-33W	Med. gr. granite or granite gneiss
3-12N-26W	Granofels (sparse)
24- 9N-29W	Mica schist
9- 9N-30W	Granofels
28- 9N-32W	Biotite adamellite
3- 9N-33W	Leucoadamellite
4- 9N-33W	Biotite adamellite
5- 9N-33W	Biotite adamellite
9- 9N-33W	Biotite granite
9- 9N-33W	Biotite adamellite
9- 9N-33W	Biotite gneiss
9- 9N-33W	Sparse granite or arkose
9- 9N-33W	Gneissic biotite granite
10- 9N-33W	Biotite granite
16- 9N-33W	Biotite granite
11- 9N-34W	Gneissic biotite adamellite
36- 9N-34W	Biotite granite
12-10N-26W	Granofels
7-10N-27W	Amphibole-biotite gneiss
13-10N-27W	Garnet-biotite schist
20-10N-29W	Hornblende schist and biotite hornblende schist
32-10N-31W	Quartzite
11-10N-32W	Arkose
11-10N-33W	Gneissic hornblende biotite granite
17-10N-34W	Quartzite
33-10N-34W	Gneissic biotite granite
22-11N-27W	Quartzite(?)
13-11N-28W	Cataclastic gneiss
8-11N-30W	Granofels
21-11N-31W	Cataclastic gneiss
8-11N-32W	Meta silicic volcanic
7-11N-33W	Cataclastic granitic gneiss
14-11N-33W	Mica schist
26-11N-34W	Hornblende biotite gneiss
16-12N-26W	Biotite granite
7-12N-30W	Cataclastic granofels
25-12N-30W	Muscovite schist
13-12N-33W	Quartz diorite
8-12N-34W	Biotite granodiorite
13-13N-27W	Biotite quartz diorite
26-13N-31W	Actinolite schist
2-13N-33W	Biotite granodiorite
32-14N-26W	Schist?

Lincoln County (continued)

28-14N-34W	Gneissic granodiorite
26-15N-28W	Cataclastic granite
28-15N-29W	Cataclastic mica schist
24-15N-31W	Biotite gneiss
23-15N-32W	Biotite granodiorite
1-15N-33W	Granofels
14-16N-26W	Meta basalt
26-16N-27W	Argillite
28-16N-29W	Hornblende schist
29-16N-31W	Granite

Logan County:

26-17N-28W	Biotite gneiss
8-17N-29W	Biotite gneiss
1-18N-28W	Biotite hornblende granodiorite
36-18N-28W	Biotite adamellite
18-19N-26W	Biotite granite
15-19N-28W	Granofels and granite(?)
33-19N-29W	Leucogranite

Loup County:

32-22N-17W	Hornblende schist
26-22N-19W	Layered hornblende gneiss
29-23N-17W	Layered muscovite-biotite gneiss and schist
14-23N-19W	Biotite gneiss
8-24N-18W	Leucogranite
26-24N-19W	Quartz-feldspar gneiss

McPherson County:

5-17N-33W	Biotite gneiss
33-17N-33W	Hornblende schist
14-17N-34W	Biotite gneiss
21-17N-34W	Arkosic sandstone
20-17N-35W	Quartz diorite biotite hornblende
21-18N-32W	Biotite gneiss
15-18N-33W	Pyroxene hornblende gneiss
17-18N-34W	Anorthositic gabbro
15-19N-31W	Gneissic muscovite biotite adamellite
25-19N-33W	Biotite
13-19N-34W	Hornblende schist
11-20N-33W	Cataclastic gneiss
17-20N-33W	Biotite hornblende gneiss

Merrick County:

11-15N- 6W	Biotite adamellite

Morrill County:

27-19N-52W	Chlorite biotite granite

Morril County (continued)

1-21N-49W	Biotite hornblende schist
27-23N-49W	Muscovite biotite adamellite

Nance County:

25-17N- 5W	Granofels
34-16N- 6W	Biotite leucoadamellite
5-16N- 7W	Granitic rock (sparse, tiny)

Nemaha County:

7- 5N-13E	Granite
21- 6N-13E	Granite
34- 6N-15E	Granite

Otoe County:

3- 7N- 9E	Altered basalt
11- 7N-10E	Arkosic quartzite and argillite
21- 7N-11E	Argillite
22- 7N-11E	Muscovite biotite gneiss
21- 7N-12E	Foliated granodiorite
7- 8N- 9E	Altered basalt
1- 8N-10E	Altered basalt
10- 8N-14E	Clastic sedimentary rock
3- 9N-12E	Altered basalt
7- 9N-12E	Clastic sedimentary rock

Pawnee County:

31- 1N-10E	Foliated hornblende biotite adamellite
13- 1N-12E	Gneissic muscovite biotite adamellite
13- 1N-12E	Gneissic biotite adamellite
34- 2N-10E	Leucogranite over quartz diorite
15- 2N-12E	Hornblende biotite granodiorite
26- 2N-12E	Leucogranite
31- 3N-11E	Gneissic quartz diorite

Perkins County:

5- 9N-35W	Gneissic biotite granite
6- 9N-36W	Biotite adamellite
28- 9N-37W	Biotite schist and leuco-adamellite
7-10N-35W	Quartzite over cataclastic granofels
23-10N-35W	Quartzite
6-10N-36W	Quartzite
9-10N-36W	Quartzite
19-10N-37W	Granofels
16-10N-39W	Quartzite over gneissic granite
23-10N-39W	Hornblende biotite gneiss
12-11N-35W	Biotite gneiss
22-11N-39W	Quartzite
19-12N-36W	Quartzite
33-12N-37W	Quartzite

Phelps County:

13- 6N-18W	Gneissic biotite adamellite
23- 6N-19W	Biotite schist
26- 6N-20W	Meta quartz latite prophyry
15- 7N-20W	Biotite quartz diorite
8- 7N-19W	Arkose(?) (3932-3990)
	Biotite schist (4000-4010)
36- 8-20W	No samples
17- 8N-19W	Quartzite

Polk County:

36-16N- 1W	Pegmatite
9-13N- 3W	Hornblende schist

Red Willow County:

5- 1N-26W	Biotite granite
5- 1N-26W	Foliated biotite granite
6- 1N-26W	Foliated biotite granodiorite
8- 1N-26W	Biotite adamellite
11- 1N-26W	Biotite hornblende adamellite
12- 1N-26W	Gneissic biotite hornblende adamellite
21- 1N-26W	Biotite granite
21- 1N-26W	Biotite leucogranite
23- 1N-26W	Biotite granite
29- 1N-26W	Leucoadamellite
1- 1N-27W	Quartz syenite
2- 1N-27W	Leucogranite
5- 1N-27W	Leucoadamellite
7- 1N-27W	Biotite granite
7- iN 27W	Muscovite biotite adamellite
12- 1N-27W	Granite
15- 1N-27W	Adamellite
16- 1N-27W	Biotite granite
17- 1N-27W	Biotite adamellite
22- 1N-27W	Muscovite biotite adamellite
22- 1N-27W	Biotite adamellite
22- 1N-27W	Biotite adamellite
23- 1N-27W	Cataclastic biotite adamellite
23- 1N-27W	Leucogranite
23- 1N-27W	Biotite adamellite
23- 1N-27W	Leucogranite
25- 1N-27W	Granite
25- 1N-27W	Biotite granite
33- 1N-27W	Granite(?)
33- iN-27W	Adamellite
36- 1N-27W	Biotite granite
2- 1N-28W	Biotite granite(?)
3- 1N-28W	Biotite granite
12- 1N-28W	Biotite granite
13- 1N-28W	Biotite granite

Red Willow County (continued)

19- 1N-28W	Biotite granite
24- 1N-28W	Biotite granite
25- 1N-28W	Biotite granite
26- iN-28W	Hornblende biotite granite
36- 1N-28W	Biotite granite
6- 1N-29W	Leucogranite
14- 1N-29W	Gneissic hornblende biotite adamellite
18- 1N-29W	Gneissic biotite hornblende granite
21- 1N-29W	Foliated biotite hornblende granite
13- 1N-30W	Leucoadamellite
21- 1N-30W	Biotite-hornblende granite
1- 2N-26W	Foliated hornblende biotite granite
3- 2N-26W	Biotite hornblende granite
7- 2N-26W	Granite
8- 2N-26W	Hornblende biotite granite
8- 2N-26W	Hornblende biotite granite
8- 2N-26W	Biotite granite
8- 2N-26W	Hornblende biotite granite
17- 2N-26W	Granite(?)
19- 2N-26W	Biotite granite
19- 2N-26W	Granite
19- 2N-26W	Biotite granite
19- 2N-26W	Biotite adamellite
19- 2N-26W	Biotite granite
19- 2N-26W	Biotite granite
21- 2N-26W	Biotite granite
26- 2N-26W	Biotite leucogranite
30- 2N-26W	Biotite granite
30- 2N-26W	Biotite granite
30- 2N-26W	Biotite granite
30- 2N-26W	Biotite granite
30- 2N-26W	Biotite hornblende granite
31- 2N-26W	Biotite hornblende adamellite
31- 2N-26W	Leucogranite
34- 2N-26W	Leucogranite
34- 2N-26W	Biotite hornblende granite
1- 2N-27W	Leucogranite
1- 2N-27W	Quartz-feldspar mylonite
1- 2N-27W	Biotite granite
2- 2N-27W	Biotite granite
2- 2N-27W	Biotite granite
2- 2N-27W	Biotite granite
2- 2N-27W	Adamellite
2- 2N-27W	Granite
2- 2N-27W	Biotite granite
2- 2N-27W	Granite(?)
2- 2N-27W	Biotite granite
2- 2N-27W	Biotite granite
2- 2N-27W	Biotite granite
3- 2N-27W	Muscovite biotite granite

<u>Red Willow County (continued)</u>

3- 2N-27W	Biotite granite
3- 2N-27W	Biotite granite
3- 2N-27W	Biotite adamellite
3- 2N-27W	Biotite granite
3- 2N-27W	Biotite adamellite
3- 2N-27W	Biotite granite
3- 2N-27W	Biotite adamellite
3- 2N-27W	Biotite granite
4- 2N-27W	Biotite granite
5- 2N-27W	Biotite adamellite
9- 2N-27W	Biotite granite
10- 2N-27W	Biotite granite
10- 2N-27W	Biotite granite
10- 2N-27W	Biotite adamellite
10- 2N-27W	Biotite adamellite
10- 2N-27W	Biotite granite
10- 2N-27W	Biotite adamellite
10- 2N-27W	Biotite granite
11- 2N-27W	Biotite granite
11- 2N-27W	Biotite adamellite
12- 2N-27W	Biotite granite
12- 2N-27W	Biotite leucogranite
12- 2N-27W	Biotite granite
13- 2N-27W	Biotite leucogranite
13- 2N-27W	Hornblende biotite granite
13- 2N-27W	Biotite granite
14- 2N-27W	Muscovite biotite adamellite
14- 2N-27W	Biotite adamellite
14- 2N-27W	Biotite Adamellite
14- 2N-27W	Biotite adamellite
15- 2N-27W	Biotite granite
20- 2N-27W	Biotite adamellite
21- 2N-27W	Biotite adamellite
24- 2N-27W	Biotite adamellite
24- 2N-27W	Granite
25- 2N-27W	Biotite granite
27- 2N-27W	Biotite adamellite
31- 2N-27W	Biotite adamellite
32- 2N-27W	Biotite leucoadamellite
35- 2N-27W	Muscovite biotite adamellite
1- 2N-28W	Biotite adamellite
3- 2N-28W	Cataclastic adamellite
3- 2N-28W	Biotite granite
5- 2N-28W	Biotite granite
8- 2N-28W	Biotite adamellite
10- 2N-28W	Biotite adamellite
11- 2N-28W	Biotite granite
12- 2N-28W	Biotite adamellite
14- 2N-28W	Biotite granite
16- 2N-28W	Biotite granite
18- 2N-28W	Granodiorite or granite
23- 2N-28W	Biotite granite
26- 2N-28W	Biotite granite

Red Willow County (continued)

29- 2N-28W	Biotite granite
33- 2N-28W	Biotite granite
34- 2N-28W	Biotite granite
1- 2N-29W	Biotite hornblende granite
4- 2N-29W	Hornblende biotite granite
8- 2N-29W	Biotite granite
8- 2N-29W	Biotite hornblende granite
15- 2N-29W	Biotite granite
16- 2N-29W	Biotite adamellite
19- 2N-29W	Biotite adamellite
26- 2N-29W	Biotite granite
29- 2N-29W	Leucogranite
32- 2N-29W	Hornblende(?) biotite granite
36- 2N-29W	Biotite granite
1- 2N-20W	Granofels
10- 2N-20W	Quartzitic granofels
12- 2N-20W	Biotite schist
20- 2N-30W	Biotite gneiss
23- 2N-20W	Quartz feldspar leucogneiss
23- 2N-30W	Quartz feldspar leucogneiss
35- 2N-20W	Biotite granite
4- 3N-26W	Hornblende biotite granite
6- 3N-26W	Granofels
9- 3N-26W	Leucogranite
11- 3N-26W	Biotite hornblende adamellite
18- 3N-26W	Hornblende biotite granite
21- 3N-26W	Leucogranite
26- 3N-26W	Granite over granite and gneiss
27- 3N-26W	Cataclastic leucoadamellite
30- 3N-26W	Leucoadamellite
30- 3N-26W	Leucogranite
31- 3N-26W	Granite(?)
32- 3N-26W	Granite
32- 3N-26W	Hornblende biotite granite
36- 3N-26W	Leucogranite
36- 3N-26W	Biotite-diopside-hornblende gneiss
3- 3N-27W	Hornblende biotite gneiss
12- 3N-27W	Leucoadamellite
14- 3N-27W	Granite
14- 3N-27W	Hornblende biotite granite
21- 3N-27W	Biotite adamellite
21- 3N-27W	Granite(?)
22- 3N-27W	Biotite adamellite
22- 3N-27W	Biotite adamellite
22- 3N-27W	Biotite granite
23- 3N-27W	Hornblende biotite granite
23- 3N-27W	Biotite granite
23- 3N-27W	Biotite leucogranite
23- 3N-27W	Hornblende biotite granite
23- 3N-27W	Hornblende biotite granite
23- 3N-27W	Biotite granite
23- 3N-27W	Biotite granite
25- 3N-27W	Biotite adamellite
25- 3N-27W	Biotite granite
26- 3N-27W	Granite
26- 3N-27W	Biotite granite

Red Willow County (continued)

26- 3N-27W	Biotite granite
27- 3N-27W	Biotite granite
27- 3N-27W	Biotite granite
27- 3N-27W	Biotite granite
27- 3N-27W	Biotite granite
29- 3N-27W	Biotite granodiorite(?)
33- 3N-27W	Altered granite(?)
35- 3N-27W	Granite
35- 3N-27W	Biotite leucogranite
25- 3N-27W	Hornblende biotite granite
35- 3N-27W	Adamellite
36- 3N-27W	Biotite granite
36- 3N-27W	Granite and granofels
1- 3N-28W	Leucoadamellite
2- 3N-28W	Hornblende biotite schist
7- 3N-28W	Biotite schist
9- 3N-28W	Chlorite adamellite
22- 3N-28W	Hornblende biotite quartz diorite
25- 3N-28W	Biotite granite
26- 3N-28W	Hornblende biotite granite
29- 3N-28W	Leucoadamellite
30- 3N-28W	Biotite hornblende adamellite
33- 3N-28W	Foliated adamellite
3- 3N-29W	Leucoadamellite
5- 3N-29W	Biotite schist and leucoadamellite
5- 3N-29W	Biotite schist
17- 3N-29W	Leucoadamellite
22- 3N-29W	Biotite adamellite
2- 3N-30W	Hornblende biotite schist
3- 3N-30W	Hornblende biotite gneiss
22- 3N-30W	Granofels
29- 3N-30W	Granofels
32- 3N-30W	Granite
35- 3N-30W	Granofels
3- 4N-26W	Biotite adamellite
11- 4N-26W	Gneissic hornblende biotite adamellite
16- 4N-26W	Granofels
26- 4N-26W	Granofels
3- 4N-27W	Granofels
12- 4N-27W	Granofels
15- 4N-27W	Altered granofels(?)
24- 4N-27W	Pyroxene biotite schist
25- 4N-27W	Hornblende biotite schist
27- 4N-27W	Biotite hornblende schist
29- 4N-27W	Granofels
6- 4N-28W	Biotite schist
10- 4N-28W	Clinopyroxene biotite schist
13- 4N-28W	Biotite schist
14- 4N-28W	Schist and granofels
17- 4N-28W	Granofels
23- 4N-28W	Biotite gneiss
24- 4N-28W	Biotite leucoadamellite

Red Willow County (continued)

26- 4N-28W	Granofels
27- 4N-28W	Granofels(?)
27- 4N-28W	Hornblende schist and granofels
30- 4N-28W	Granofels
34- 4N-28W	Layered hornblende gneiss
35- 4N-28W	Granofels
22- 4N-29W	Granofels
31- 4N-29W	Granofels
35- 4N-29W	Biotite adamellite
36- 4N-29W	Biotite gneiss
6- 4N-30W	Muscovite biotite schist
8- 4N-30W	Biotite gneiss
12- 4N-30W	Granofels
17- 4N-30W	Granofels(?)
24- 4N-30W	Granofels
33- 4N-30W	Granofels
35- 4N-30W	Orthopyroxene hornblende granulite

Richardson County:

14- 1N-13E	Foliated biotite granodiorite
30- 1N-13E	Hornblende schist over biotite hornblende gneiss
9- 1N-14E	Granite(?)
14- 1N-14E	Mylonite
17- 1N-14E	Cataclastic gneiss
26- 1N-14E	Completely altered rock
30- 1N-14E	Cataclastic foliated granite
5- 2N-13E	Biotite gneiss
6- 2N-13E	Mylonite
30- 2N-13E	Basalt
32- 2N-14E	Biotite gneiss
35- 2N-17E	Leucogranite over cataclastic foliated granite
28- 3N-13E	Biotite granite
30- 3N-13E	Mylonite
31- 3N-13E	Biotite gneiss
4- 3N-16E	Muscovite biotite granite
8- 3N-16E	Muscovite biotite granite

Rock County:

9-25N-17W	Hornblende biotite schist
22-25N-17W	Muscovite biotite schist
14-25N-19W	Muscovite biotite schist
22-26N-18W	Biotite chlorite schist
26-27N-19W	Biotite schist
10-20N-19W	Hornblende schist(?)
24-31N-18W	Muscovite biotite schist

Saline County:

35- 8N- 2E	Muscovite biotite schist

Sarpy County:

3-12N-11E	Argillite
20-13N-11E	Olivine basalt
23-13N-11E	Metabasalt
23-13N-11E	Altered gabbro
33-13N- 7E	Metabasalt
28-13N- 8E	Ophitic basalt
6-13N-10E	Sandstone
11-15N- 7E	Arkosic sandstone and argillite
33-15N- 8E	Argillaceous sandstone

Seward County:

23- 9N- 4E	Ophitic basalt
14-10N- 4E	Argillaceous sandstone

Sheridan County:

20-24N-41W	Biotite granite
10-26N-42W	Cataclastic biotite granite
20-26N-44W	Chlorite adamellite
17-26N-46W	Biotite hornblende gneiss
19-27N-44W	Biotite hornblende gneiss
33-28N-43W	Granite(?)
14-28N-46W	Granofels
22-31N-46W	Chlorite schist
16-32N-45W	Biotite gneiss
24-32N-46W	Biotite hornblende schist
27-33N-43W	Hornblende biotite granodiorite, gneissic

Sherman County:

7-16N-13W	Biotite quartz diorite

Sioux County:

13-27N-57W	Hornblende biotite granodiorite
17-27N-57W	Biotite muscovite gneiss
27-30N-56W	Biotite hornblende gneiss
23-31N-54W	Biotite schist
4-33N-54W	Biotite granite
10-34N-54W	Biotite adamellite

Stanton County:

33-21N- 2E	Weathered granite or granofels
12-21N- 1E	Recrystallized silicic volcanic
10-22N- 1E	Weathered basement rock
9-23N- 1E	Cataclastic gneiss

Thayer County:

33- 3N- 1W	Hornblende biotite monzonite

Valley County:

29-18N-13W	Gabbro
6-19N-16W	Hornblende granite

Wheeler County:

7-21N-10W	Hornblende biotite schist
12-21N-10W	Granite
3-21N-12W	Biotite hornblende gneiss
20-22N-11W	Chlorite schist
26-22N-12W	Amphibolite

York County:

11-12N- 2W	Granofels

NORTH DAKOTA

Barnes County:

Location	Rock Type
9-140N-59W	No samples
20-142N-61W	Actinolite-biotite gneiss

Benson County:

Location	Rock Type
31-154N-70W	Altered biotite granodiorite

Billings County:

Location	Rock Type
10-139N-101W	Foliated biotite tonalite

Bottineau County:

Location	Rock Type
31-162N-78W	Serpentinite
31-160N-81W	Hornblende schist
20-159N-81W	Chlorite schist
8-163N-81W	~~Jprmb;emde=boptote~~ granodiorite
6-161N-79W	Hornblende schist
14-162N-77W	Foliated hornblende-biotite granodiorite
23-163N-75W	Biotite granite
18-163N-77W	Foliated biotite trondhjemite

Burleigh County:

Location	Rock Type
32-137N-76W	Biotite hornblendegneiss
31-138N-78W	Talc-chlorite schist
36-139N-76W	No crystalline rocks seen.
9-140N-75W	Altered gneissic biotite granite
3-140N-77W	Altered biotite granite gneiss
6-140N-77W	Muscovite-biotite granite
18-140N-80W	No crystalline rocks seen

Cass County:

Location	Rock Type
139N-49W	No samples
33-140N-53W	Chlorite schist; migmatitic gneiss
15-142N-52W	Trondhjemite

Cavalier County:

Location	Rock Type
16-159N-59W	No samples
28-159N-63W	Hornblende-biotite-gneiss
3-160N-57W	Biotite granite gneiss
10-162N-63W	Biotite granodiorite

Dickey County:

11-129N-63W	Actinolite schist
14-129N-63W	Biotite granite gneiss
22-129N-66W	No samples
16-162N-96W	Hornblende-biotite trondhjemite gneiss
9-148N-62W	Zoisite-actinolite schist
8-150N65W	Hornblende schist and granofels
16-150N-67W	Biotite-granite

Emmons County:

8-132N-78W	Biotite granodiorite gneiss
35-133N-75W	Biotite granite
35-133N-76W	Biotite-hornblende granodiorite-gneiss

Foster County:

26-145N-62W	Foliated biotite granodiorite
24-145N-64W	Mylonitic biotite trondhjemite
10-146N-67W	Foliated biotite granite
18-146N-62W	Biotite tonalite gneiss
13-146N-63W	Chlorite-actinolite schist
8-146N-65W	Serpentinite
15-146N-66W	Actinolite schist
23-146N-66W	Altered Biotite granite
25-147N-64W	Hornblende schist

Grand Forks County:

15-151N-53W	Muscovite-biotite granodiorite
17-152N-51W	Hornblende schist and gneissic biotite granodiorite
35-152N-51W	Biotite-hornblende tonalite gneiss
35-152N-51W	Foliated diorite
22-152N-54W	Biotite granodiorite
24-152N-54W	Hornblende-biotite tonalite schist
5-153N-52W	Muscovite biotite granodiorite

Hettinger County:

26-133N-93W	Biotite-hornblende granodiorite gneiss

Kidder County:

36-141N-73W	Leucogranite
16-143N-71W	Granite(?)

La Moure County:

22-133N-61W	Biotite granodiorite gneiss
12-133N-65W	Foliated biotite granodiorite

Logan County:

25-136N-71W	Mica schist
29-135N-73W	No samples

McHenry County:

3-157N-78W	Biotite granite

McIntosh County:

13-130N-69W	Biotite trondhjemite
19-130N-69W	Gneissic muscovite biotite
17-131N-69W	Biotite granite
15-131N-73W	Granite(?)

McKenzie County:

1-152N-95W	Charnokitic tonalite gneiss
6-148N-104W	Foliated biotite-muscovite gneiss

Morton County:

29-136N-81W	Biotite-epidote granite
34-135N-83W	foliated biotite granite

Montrail County:

24-151N-89W	Foliated hornblende-biotite granodiorite
16-153N-88W	Muscovite schist

Nelson County:

18-152N-58W	Muscovite biotite granodiorite
5-152N-60W	Hornblende schsit
32-151N-61W	No samples
6-151N-60W	Chlorite schist

Oliver County:

18-141N-81W	Diabase
11-161N-54W	Altered iron-oxide formation (1390-1470); and Biotite-quartz schist (1470-1512)
8-160N-54W	Biotite-quartz schist(1270-1400); iron oxide formation; (1400-1441) silicate-magnetite iron formation (1441-1474)

Pembina County:

35-162N-53W	No samples
8-163N-55W	Nosamples
28-164N-56W	Gneissic hornblende-biotite granodiorite

Pierce County:

23-157N-70W	Biotite granite(?)
12-158N-69W	Biotite-granite

Ramsey County:

1-153N-63W	Hornblende-biotite granodiorite gneiss
32-156N-61W	No samples
13-153N-63W	No samples
36-154N-63W	Biotite-granite
16-154N-65W	Biotite-hornblende granodiorite-gneiss
17-158N-62W	Altered foliated biotite granite
29-158N-62W	Foliated biotite granite
33-158N-62W	Foliated biotite granite
14-156N-62W	No samples
11-158N-63W	No samples

Renville County:

34-164N-87W	Biotite gneiss
10-163N-87W	Biotite tonalite gneiss
5-163N-87W	Chlorite schist
3-163N-87W	Garnet biotite gneiss
16-163N-87W	Garnet-biotite gneiss
1-162N-87W	Foliated biotite granodiorite
2-161N-85W	Mylonite(?)

Richland County:

22-130N-47W	No samples
11-132N-48W	Chlorite schist
19-130N-51W	Metagraywacke
25-130N-51W	Tonalite; granodiorite gneiss
11-132N-52W	Talc-chlorite schist
22-132N-50W	Quartz-monzonite
29-135N-52W	Meta-lapilli tuff
7-132N-49W	Biotite trondhjemite
16-132N49W	Biotite granodiorite

Rolette County:

23-160N-70W	Muscovite biotite granite
23-161N-73W	Biotite granodiorite

Sargent County:

11-130N-56W	Meta-basalt; meta-tuffaceous
9-129N-58W	Biotite granodiorite

Stutsman County:

25-137N-67W	Actinolite schist

Stutsman County (continued)

26-138N-67W	Cataclastic quartz feldspar gneiss
12-139N-67W	Foliated leucogranite
24-139N-68W	Foliated biotite granite
5-139N-68W	Actinolite gneiss
35-139N-68W	Gneissic biotite granodiorite
20-140N-65W	Altered gneissic biotite-granodiorite
21-140N-65W	No crystalline rocks present.
12-140N-67W	No samples
11-141N-67W	Biotite-granodiorite gneiss
21-142N-63W	Actinolite schist
15-142N-65W	Cataclastic gneissic-biotite granite

Towner County:

17-157N-65W	No samples
31-158N-66W	Biotite granite
24-160N-67W	Biotite granite
35-161N-68W	Hornblende-biotite tonalite gneiss
18-163N-65W	Hornblende-biotite gneiss
27-163N-68W	Hornblende biotite granite

Traill County:

27-145N-52W	Meta-basalt
21-148N-52W	Foliated granodiorite; trondhjemite
25-148N-50W	Granodiorite gneiss
15-148N-51W	No samples

Walsh County:

9-156N-58W	Biotite tonalite gneiss
13-157N-53W	No samples
8-156N-56W	Biotite-granodiorite gneiss

Ward County:

23-155N-81W	No crystalline rocks seen

Wells County:

8-146N-68W	Biotite-muscovite granodiorite gneiss
27-146N-73W	Biotite-muscovite trondhjemite

Williams County:

2-155N-96W	Altered monzonite
15-155N-96W	Altered monzonite
1-155N-96W	Hornblende-biotite syenite
17-156N-103W	Biotite tonalite gneiss
16-156N-95W	Charnokitic biotite-tonalite gneiss
34-156N-96W	Basement no reached

OHIO

Adams County:

Township	Location	Rock Type
Jefferson	VMSL 2662	Qtz. Monzonite
Jefferson	VMSL 4040	Granite

Ashtabula County:

Township	Location	Rock Type
Morgan	lot 19, 500'NL, 725'WL	Amphibolite
Pierpont	lot 60, 62'SL, 231.5'EL	Hb/Bt Schist
Trumball	lot 30N, 330'SL,460'WL	Granite

Auglaise County:

Township	Location	Rock Type
St. Marys	500'SL & 600'WL of NW¼ Sec. 22	Arkose

Butler County:

Township	Location	Rock Type
Lemon	1055'NL & 65'WL of NW¼ Sec. 8	Arkose
Lemon	1190'NL & 1365'WL of NW¼ Sec. 8	Arkose

Clark County:

Township	Location	Rock Type
Harmony	81'NL & 454'EL of SE¼ Sec. 3	Diorite
Madison	11½ Mi. SE of Springfield	Volcanic ?
Pleasant	3399'SL & 1598'WL of VMSL 4673	Gabbro

Clermont County:

Township	Location	Rock Type
Stonelick	VMSL 681	Basalt

Clinton County:

Township	Location	Rock Type
Wayne	2400'W of 83 40' & 950'S of 39 25'	Amphibolite
Wayne	11200'W of 83 35' & 12800'S of 39 25'	Basalt
Wayne	VMSL 1065	Gabbro

Columbiana County:

Township	Location	Rock Type
Hanover	Sec. 12	Mt. Simon

Coshocton County:

Township	Location	Rock Type
Jefferson	6960'SL & 2420'El of Twsp.	Qtz. Monzonite

Crawford County:

Chatfield	1090'SL & 230'EL of SE¼ Sec. 34	Granite

Cuyahoga County:

Brooklyn	Lot 85	Granite

Delaware County:

Brown	Lot 7 (2q)	Hb Gneiss
Genoa	Lot 4 (4q)	Granite
Oxford	Lot 5 (1q)	Granite
Porter	Lot 6 (1q)	Trondhjemite
Orange	Lot 11 (3q)	Granitic Gneiss

Erie County:

Florence	Lot 98	Granite
Florence	Lot 97 (1q)	Gneiss
Florence	Lot 48 (4q)	Schist

Fayette County:

Jasper	800'E of 83 35' & 2250'N of 39 35'	Gabbro
Union	300'E of 83 25' & 700'S of 39 30'	Gabbro, Granite Marble Amphibolite
Concord	3800'W of 83 30' & 13600'N of 39 25'	Bt. Gneiss

Franklin County:

Franklin	2500'S of Trabue RD. & 3100'W of Scioto River	Granite

Fulton County:

Swann Creek	330'NL & 2310'W of SW¼ Sec. 27	Latite

Guernsey County:

Adams	625'WL & 547'SL of SW¼ Sec. 15	Trondhjemite

Hancock County:

Amanda	990'SL & 330'WL of SW¼ Sec. 20	Granitic Gneiss
Jackson	2100'SL & 1900'EL of SE¼ Sec. 6	Schist

Hancock County (continued)

Marion	3 mi NE of Findlay	Granite
Union	330'SL & 760'EL of SE¼ Sec. 24	Quartzite

Highland County:

Fairfield	Undivided lands Va. Military Dist.	Hb/Bt Schist
Fairfield	1500'NL & 13,700'NWL of Twsp.	Mt. Simon

Hocking County:

Starr	660'SL & 750'WL NE¼ Sec. 31	Granite

Huron County:

Peru	7900'EL & 2350'NL of Twsp.	Hb/Bt Gneiss

Jackson County:

Hamilton	1000'EL & 235'NL of SE¼ Sec. 28	Granite
Franklin	790'SL & 730'EL SW¼ Sec. 23	Amphibolite

Knox County:

Milford	1600'WL & 836'NL of Sec. 10	Monzodiorite
Hilliar	500'NL & 985'WL of Lot 21	Granitic Gneiss

Lake County:

Perry	1527'SL & 435'EL of Lot 47	Hb/By Schist

Licking County:

Hartford	300'EL & 1800'SL of Lot 2	Granite
Lima	1210'SL & 1100'WL of Lot 16	Gabbro
MaryAnn	Lot 15	Mylonitic Granite

Logan County:

McArthur	VMSL 9930	Rhyolite

Lorain County:

Henrietta	5850'WL & 4660'Sl of Twsp.	Granodiorite

Lucas County:

Harding	300'SL & 500'EL of SE¼ Sec. 9	Bt/Gt. Schist

Madison County:

Fairfield	VMSL 9717	Mylonitic Granite

Marion County:

Claridon	Sec. 27 NE	Gneiss

Medina County:

Granges	540'NL & 786'WL of Lot 42	Bt/Schist, Granite
Homer	Sec. 20	Granite
Hinckley	821'E/W line & 853'N/S line Lot 69	Granite

Miami County:

Lost Creek	330'N/S & 990'W/E line of NW¼ Sec. 13	Basalt
Washington	330'N/S & 990'W/E line of NW¼ Sec. 3	Basalt ?

Morrow County:

Bennington	Lot 13 (3a)	Granite
Canaan	Sec. 19 (SW)	Granite
Canaan	Sec. 33 (NW)	Granite
Peru	Lot 16 (1Q)	Granite
Troy	Sec. 18 (NW)	Granodiorite

Nobel County:

Elk	1120'NL & 270'WL of SE¼ Sec. 31	Diorite

Paulding County:

Jackson	300'SL & 1370'EL of SE¼ Sec. 14	Granite

Pickaway County:

Monroe	10560'NL & 20290'WL of Twsp.	Gabbro

Pickaway County (continued)

Jackson	VMSL 7974	Gneiss
Pickaway	Sec. 7W (NE)	Bt. Schist

Putnam County:

Liberty	500'WL & 330'SL of SW¼ Sec. 29	Granite

Richland County:

Washington	Sec. 14 (SW)	Hb/Bt Gneiss

Ross County:

Concord	VMSL No. NA	Granitic Gneiss

Sandusky County:

Sandusky	1270'NL & 1878'EL of NE¼ Sec. 26	Granite
Towsend	1320'N/SL & 1000'E/WL of NW¼ Sec. 31	Granite
Washington	230'NL & 330'EL of SE¼ Sec. 31N	Granite
Woodville	660'SL & 1980'EL of NW¼ Sec. 36	Gneiss
Woodville	Sec. (NW)	Schist

Scioto County:

Green	7360'SL & 550'WL of Twsp.	Granitic Gneiss

Seneca County:

Adams	744'NL & 917'EL of NE¼ Sec. 31	Amphibolite
Hopewell	330'NL & 525'EL of Sec. 4	Mylonitic Gneiss
Liberty	700'SL & 700'WL of Sec. 34	Bt. Gneiss

Shelby County:

Perry	350'WL & 330'NL of SW¼ Sec. 20	Basalt
Salem	330'WL & 330'NL of NW¼ Sec. 3 (NW)	Basalt

Union County:

Union	800'NL & 800'WL of VMSL 7474	Granitic Gneiss

Wayne County:

Chippewa	1179'WL & 237'SL of SW¼ Sec. 21	Gt. Bt. Gneiss
Wayne	1007'SL & 330'WL of SE¼ Sec. 14	Hb. Gneiss

Williams County:

St. Joseph	311-SL & 350'EL of NE¼ Sec 21	Trachyte

Wood County:

Liberty	1560'WL & 230'SL of SW¼ Sec. 36	Granitic Gneiss
Center	990'NL & 330'EL of SE¼ Sec. 4	Granite
Center	990'EL & 330'NL of SW¼ Sec. 31	Granitic Gneiss
Middleton	660'SL & 615'EL of SE¼ Sec. 21W	Bt Schist
Plain	332'NL & 437'EL of NW¼ Sec. 1	Amphibolite

Wyandot County:

Eden	1282'NL & 312'WL of SE¼ Sec. 3	Syenite
Mifflin	330'NL & 330'EL of NW¼ SEc. 14	Syenite
Salem	990'EL & 330'SL of SW¼ Sec. 31	Granite
Crawford	Sec. 18 (NW)	Granite
Jackson	330'NL & 330'EL of NE¼ Sec. 36	Granite

OKLAHOMA PANHANDLE

Cimarron County:

Location	Rock Type
15- 3N-3ECM	Rhyolite porphyry
28- 3N-6ECM	Granite
23- 4N-2ECM	Micrographic granite
16- 5N-8ECM	Granite
33- 6N-2ECM	Granite
24- 6N-3ECM	Rhyolite porphyry

NORTHEASTERN OKLAHOMA

Cherokee County:

Location	Rock Type
33-16N-21E	Micrographic granite porphyry
35-19N-21E	Micrographic granite porphyry
20-19N-23E	Micrographic microgranite porphyry
15-17N-22E	Rhyolite porphyry

Craig County:

Location	Rock Type
20-24N-21E	Granite
4-26N-19E	Rhyolite porphyry
12-26N-21E	Micrographic granite porphyry
19-28N-20E	Welded andesite tuff
31-28N-20E	Welded andesite tuff

Creek County:

Location	Rock Type
3-16N- 7E	Micrographic granite porphyry
22-17N- 7E	Micrographic granite porphyry
10-17N- 7E	Micrographic granite porphyry
17-17N-12E	Pyroxene micrographic granite porphyry
4-18N- 7E	Micrographic microgranite porphyry
8-18N- 7E	Micrographic microgranite porphyry
29-18N-12E	Micrographic granite porphyry

Delaware County:

Location	Rock Type
19-20N-24E	Rhyolite porphyry
6-20N-23E	Rhyolite porphyry
24-20N-23E	Rhyolite porphyry
18-20N-22E	Micrographic granite porphyry
17-23N-25E	Micrographic granite porphyry
23-20N-23E	Microgranite porphyry
25-20N-23E	Microgranite porphyry

Garfield County:

Location	Rock Type
18-22N- 3W	Granite
31-23N- 3W	Granite

Haskell County:

Location	Rock Type
36- 8N-22E	Metarhyolite porphyry

Kay County:

Location	Rock Type
8-25N- 2E	Granite
17-28N- 1E	Granite
18-28N- 3E	Metarhyolite porphyry

LeFlore County:

Location	Rock Type
28- 8N-23E	Hornblende granite

Lincoln County:

6-16N- 6E	Granite

Mayes County:

8-20N-19E	Granite?
26-19N-18E	Rhyolite porphyry
13-22N-19E	Micrographic granite porphyry
8-22N-20E	Micrographic granite porphyry
31-22N-21E	Micrographic granite porphyry
31-23N-19E	Micrographic granite porphyry
17-23N-19E	Micrographic granite porphyry
15-23N-19E	Micrographic granite porphyry
34-23N-21E	Micrographic granite porphyry

Muskogee County:

23-13N-19E	Altered rhyolite porphyry
32-15N-18E	Micrographic microgranite porphyry

Noble County:

15-23N- 2W	Granite
17-20N- 2W	Granite
27-22N- 2W	Not observed

Nowata County:

20-27N-15E	Rhyolite porphyry

Oklahoma County:

19-11N- 2W	Sheared granite and diabase
15-12N- 3W	Granite gneiss

Okmulgee County:

26-12N-13E	Micrographic microgranite
12-13N-13E	Micrographic granite porphyry
11-14N-11E	Rhyolite porphyry
24-16N-12E	Micrographic microgranite porphyry

Osage County:

5-20N-11E	Micrographic granite
8-20N-12E	Welded rhyolite tuff
9-20N-12E	
28-20N-12E	Banded rhyolite porphyry
1-21N- 7E	Rhyolite porphyry
9-21N- 9E	Rhyolite porphyry
9-21N- 9E	Microgranite porphyry
5-21N-11E	Altered rhyolite porphyry
32-21N-12E	Welded rhyolite tuff
33-22N- 7E	Altered rhyolite porphyry
14-22N- 8E	Microgranite porphyry

Osage County (continued)

24-22N- 9E	Microgranite porphyry
33-22N-10E	Rhyolite porphyry
34-22N-10E	Rhyolite porphyry
9-22N-11E	Rhyolite porphyry
12-23N- 7E	Rhyolite porphyry
8-23N- 8E	Microgranite porphyry
9-23N- 8E	Microgranite porphyry
25-23N- 8E	Microgranite porphyry
7-23N- 8E	Microgranite porphyry
8-23N-11E	Rhyolitic arkose
28-24N- 7E	Rhyolite porphyry
16-24N- 8E	Microgranite porphyry
8-24N-11E	Banded rhyolite porphyry
24-20N-11E	Rhyolite porphyry
17-21N-10E	Rhyolite Arkose
13-22N- 7E	Altered rhyolite porphyry
24-24N- 9E	Microgranite porphyry
20-23N- 8E	Microgranite porphyry
25-24N-11E	Rhyolite porphyry
19-25N- 8E	Rhyolite porphyry
23-25N- 8E	Welded rhyolite tuff
29-25N- 8E	Microgranite porphyry
31-25N-10E	Microgranite porphyry
20-25N-11E	Rhyolite porphyry
14-26N- 6E	Metarhyolite (tuff?)
11-27N- 5E	Metarhyolite porphyry
22-27N- 8E	Rhyolite porphyry

Ottawa County:

8-28N-22E	Micrographic granite porphyry
8-28N-22E	Micrographic granite porphyry
24-28N-22E	Micrographic granite porphyry
13-29N-22E	Micrographic granite porphyry
19-29N-23E	Micrographic granite porphyry
19-29N-23E	Microgranite porphyry
20-29N-23E	Andesite porphyry

Pawnee County:

20-21N- 8E	Rhyolite porphyry
3-20N- 8E	Rhyolite porphyry
9-20N- 8E	Welded rhyolite tuff
20-20N- 8E	Rhyolite porphyry
33-23N- 3E	Rhyolite porphyry

Payne County:

4-18N- 5E	Micrographic granite porphyry
34-19N- 4E	Micrographic granite porphyry
33-19N- 5E	Micrographic granite porphyry

Pottawatomie County:

19- 7N- 5E	Granite

Rogers County:

25-19N-17E	Granite
27-19N-17E	Granite
36-21N-16E	Micrographic microgranite and granite porphyry with syenitic dikes
25-22N-14E	Rhyolite porphyry
9-21N-15E	Rhyolite porphyry

Seminole County:

23- 9N- 6E	Granite
34- 9N- 6E	Granite

Sequoyah County:

20-11N-26E	Rhyolite porphyry
15-13N-25E	Rhyolite porphyry

Tulsa County:

4-16N-13E	Micrographic microgranite porphyry
27-17N-14E	Micrographic granite porphyry
23-19N-11E	Pyroxene micrographic granite porphyry
6-19N-12E	Altered welded rhyolite tuff and rhyolite porphyry
23-19N-12E	Micrographic granite porphyry
31-20N-13E	Micrographic granite porphyry
26-21N-13E	Rhyolite porphyry
32-21N-13E	Rhyolite tuff flow

Wagoner County:

5-16N-16E	Micrographic granite porphyry
18-17N-17E	Pyroxene rhyolite porphyry
29-18N-18E	Pyroxene rhyolite porphyry
6-18N-18E	Rhyolite porphyry

Washington County:

27-24N-13E	Rhyolite porphyry
25-25N-12E	Rhyolite porphyry (tuff?)
20-26N-13E	Welded rhyolite tuff
3-27N-13E	Welded rhyolite tuff
8-27N-14E	Rhyolite porphyry
30-28N-13E	Welded rhyolite tuff
22-29N-13E	Rhyolite tuff

SOUTHERN OKHLAHOMA

Atoka County:

Location	Rock Type
26- 4S-10E	Granite
14- 4S-10E	Granite
20- 4S-10E	Altered diorite
25- 3S- 9E	Granite and diabase

Beckham County:

Location	Rock Type
34-10N-25W	Granite
10- 9N-25W	Rhyolite and rhyolite hornfels intruded by a microgramite sill
11- 9N-25W	Granite
27- 9N-25W	Granite
34- 9N-25W	Granite
8- 7N-25W	Diorite cut by a dike or sill or granite
11- 7N-25W	Granite
27- 7N-25W	Rhyolite tuff
27- 8N-25W	Diorite
15- 9N-23W	Granite
27- 9N-23W	Granite and diabase
31- 9N-23W	Granite
34- 9N-22W	Granite
8- 8N-22W	Granite
12- 8N-22W	Granite
24- 8N-22W	Granite
28- 8N-22W	Gabbro cut by diabase
31- 9N-21W	Granite cut by diabase
32- 9N-26W	Granite
21- 8N-26W	Granite
31- 8N-26W	Diorite
33- 1N-26W	Gabbro cut by a dike or sill of granite
7- 7N-26W	Diorite and quartz diorite
35- 9N-26W	Granite
34- 8N-21W	Gabbro
11- 8N-26W	Granite
7- 8N-26W	Diorite

Bryan County:

Location	Rock Type
27- 5S-10E	Andesine diabase from slush pit
24- 5S-11E	Granite cut by numerous dikes and sills of diorite and diabase
9- 7S-10E	Cataclastic granite cut by dikes and sills of diabase
1- 7S- 9E	Granite and diabase
30- 5S- 8E	Granite and diabase

Carter County:

6- 5S- 1W	Rhyolite

Comanche County:

11- 4N-12W	Rhyolite and rhyolite tuff; Granite and diabase; Spilite, basalt and tuff
33- 3N-10W	Rhyolite
3- 2N-10W	Altered rhyolite
6- 2N- 9W	Diabase
9- 2N- 9W	Rhyolite
30- 2N- 9W	Rhyolite
4- 1S-11W	Spilite(?)
21- 2N- 9W	Rhyolite
30- 1S-13W	Granite
34- 3N-10W	Altered rhyolite
24- 2N-10W	Rhyolite
28- 2N-10W	Rhyolite
7- 1S-12W	Rhyolite

Cotton County:

20- 2S-13W	Meta-graywacke
26- 2S-13W	Meta-graywacke
6- 3S-11W	Rhyolite
31- 4S- 9W	Rhyolite
1- 4S-11W	Rhyolite and diabase
15- 3S-12W	Granite

Garvin County:

34- 1N- 1W	Rhyolite
20- 1N- 2W	Rhyolite
26- 1N- 2W	Rhyolite; Granite
9- 1N- 3W	Rhyolite

Greer County:

7- 7N-23W	Granite
1- 7N-22W	Granite
15- 7N-22W	Gabbro
16- 7N-21W	Gabbro
3- 6N-24W	Rhyolite
17- 6N-24W	Rhyolite and diabase
23- 6N-24W	Rhyolite
30- 4N-22W	Granite
6- 4N-21W	Diabase
5- 3N-22W	Granite
2- 3N-23W	Granite?
26- 6N-22W	Granite
34- 7N-24W	Rhyolite
11- 6N-24W	Rhyolite
26- 6N-22W	Granite
27- 6N-22W	Granite
22- 6N-22W	Gabbroic diorite
28- 6N-22W	Granite
35- 6N-22W	Granite
23- 6N-22W	Granite
26- 6N-22W	Granite
22- 6N-23W	Gabbroic diorite

Greer County (continued)

1- 6N-24W	Rhyolite
25- 6N-25W	Rhyolite tuff
24- 6N-24W	Rhyolite
14- 6N-24W	Rhyolite
10- 6N-24W	Rhyolite

Jackson County:

23- 4N-21W	Granite and diabase
9- 3N-21W	Andesite and silicified andesite
13- 3N-20W	Granite
10- 3N-19W	Basic hornfels cut by numerous dikes and sills of granite
31- 3N-19W	Granite
34- 3N-19W	Meta-graywacke and argillite
3- 1N-20W	Rhyolite hornfels
4- 1N-20W	Microgranite
5- 1N-20W	Microgranite
9- 1N-20W	Microgranite
11- 1N-20W	Silicified rhyolite
23- 1N-20W	Meta-basalt
33- 2N-18W	Meta-graywacke
9- 2N-19W	Bedded chert
31- 3N-19W	Granite
10- 1N-20W	Rhyolite and diabase

Jefferson County:

36- 5S- 9W	Granite
30- 5S- 8W	Rhyolite
30- 5S- 8W	Rhyolite
13- 7S- 6W	Granite
14- 7S- 6W	Biotite schist
22- 3S- 5W	Rhyolite
32- 6S- 6W	Granite
35- 7S- 6W	Granite

Johnston County:

36- 4S- 8E	Altered diorite
6- 5S- 8E	Diabase from slush pit
7- 5S- 8E	Granite from slush pit
9- 4S- 7E	Granite from slush pit
34- 2S- 8E	Granite; 15-765 faulted

Kiowa County:

23- 7N-20W	Anorthosite
2- 7N-18W	Granite
5- 7N-18W	Microgranite
10- 7N-18W	Diabase
14- 7N-18W	Granite or quartz monzonite
28- 7N-18W	Granite
35- 7N-18W	Olivine-pyroxene rock
30- 7N-17W	Basalt cut by granite
13- 6N-18W	Gabbro cut by microgranite
22- 6N-17W	Anorthosite
11- 6N-15W	Rhyolite

Kiowa County:

3- 4N-16W	Gabbro
33- 2N-16W	Basic hornfels
22- 6N-17W	Anorthosite
32- 7N-17W	Basalt cut by granite
7- 6N-17W	Gabbro
28- 7N-19W	Granite
30- 7N-17W	Basalt cut by granite
14- 6N-15W	Diabase
35- 7N-15W	Rhyolite
29- 6N-17W	Anorthosite
14- 5N-18W	Anorthosite
35- 7N-15W	Rhyolite and diabase
10- 6N-18W	Gabbro
11- 6N-15W	Rhyolite
24- 3N-16W	Gabbro
25- 5N-15W	Diabase
30- 2N-16W	Gabbro
32- 5N-16W	Gabbro
31- 5N-17W	Contaminated granite
4- 5N-15W	Rhyolite

Murray County:

32- 1S- 1W	Rhyolite and tuffs; Granite and diabase
25- 1S- 4E	Granite
19- 2N- 3E	Granite
1- 1S- 1W	Rhyolite and diabase

Pontotoc County:

15- 2N- 6E	Granite
27- 3N- 5E	Granite
27- 1N- 5E	Granite and diabase
31- 2N- 7E	Granite

Stephens County:

24- 2N- 9W	Rhyolite and tuff Spilite
25- 2N- 9W	Rhyolite
34- 2N- 9W	Rhyolite
3- 1N- 9W	Rhyolite
3- 1N- 9W	Rhyolite
7- 1N- 8W	Diabase
24- 1S- 7W	Rhyolite
16- 1S- 8W	Rhyolite

Tillman County:

10- 1N-18W	Meta-graywacke
21- 1N-17W	Meta-graywacke
33- 1N-17W	Meta-graywacke
22- 1N-16W	Meta-basalt
30- 1S-16W	Meta-graywacke and hornfels
6- 2S-16W	Meta-graywacke
11- 2S-16W	Biotite schist cut by granite
11- 2S-16W	Biotite schist cut by granite

Tillman County (continued)

33- 1S-16W	Biotite & muscovite schists
19- 2N-17W	Quartz diorite
13- 1N-17W	Micrograbbro and gabbro

Washita County:

21- 8N-18W	Altered rhyolite
21- 8N-18W	Altered rhyolite and tuffs;
30- 8N-20W	Gabbroic rocks; Cut by granite
33- 8N-18W	Granite

SOUTH DAKOTA

Aurora County:

Location	Rock Type
11-103N-66W	Sioux Formation
1-104N-64W	Sioux Formation
28-104N-63W	No samples

Beadle County:

17-110N-62W	Granite(?)
1-110N-62W	Granite(?)
22-111N-64W	No samples

Bon Homme County:

8- 96N-58W	Siox Formation
8- 93N-59W	Calcareous quartz sandstone
10- 93N-60W	No samples

Brookings County:

25-111N-52W	Hornblende biotite granodiorite

Brown County:

24?-123N-64W	Granite(?)

Brule County:

3-103N-68W	Sioux Formation
14-103N-71W	Sioux Formation
28-104N-71N	Redqtz. sandstone (Sioux)

Butte County:

14- 9N- 8E	Biotite gneiss
7- 9N- 9E	Quartz diorite gneiss

Clay County:

31-94N-50W	Sioux Formation

Codington County:

10-119N-51W	No crystalline rocks seen

Carson County:

11-22N-19E	Biotite granite sparse
20-23N-23E	No samples

Custer County:	
2- 4S- 2E	Muscovite-biotite schist
Davison County:	
25-103N-61W	Gneissic biotite granodiorite
Day County:	
32-121N-55W	Biotite granite
Deul County:	
36-113N-48W	Muscovite biotite schist
Dewey County:	
32-13N-22E	Muscovite biotite gneiss
25-16N-22E	Chlorite muscovite schist
13-13N-27E	
Douglas County:	
5-98N-64W	Sioux Formation
18-100N-62W	Sioux Formation
Fall River County:	
3- 10S- 2E	Biotite schist
20- 10S- 4E	Granite(?)
25-10S- 8E	Muscovite biotite schist and muscovite granite
8-12S- 6E	No bottom hole samples
Faulk County:	
20-118-72	Altered Microgranite(?)
Grant County:	
7?-120N-48W	Granite(?)
Haakon County:	
36- 6N-21E	Qtz-Flsp-Bio Schist
33- 3N-19E	Hornblende biotite adamellite
31- 4N-24E	No bottom hole samples
21- 4N-18E	No samples
6- 4N-21E	No samples
Hand County:	
4-109N-70W	Granite(?) and Sioux Formation

Hanson County:

7-102N-59W	Sioux Formation
16?-104N-57W	Granite(?)
18-104N-57W	Sioux Formation

Harding County:

28-21N- 1E	Muscovite biotite grano-diorite
12-21N- 4E	No samples
35-18N- 4E	Qtz-Flsp-Mica Schist Musc.

Hughes County:

35-111N-79W	No crystalline rocks seen
27-112N-76W	Gneissic biotite granodiorite

Hutchinson County:

10?-97N-57W	Sioux Formation
9-99N-56W	Sioux Formation
29-99N-59W	Sioux Formation
17-99N-61W	Sioux Formation
1-97-56W	Sioux Qtz. (no samples)

Hyde County:

24-116N-73W	Altered basalt
31-116N-73W	No samples

Jackson County:

16- 1S-22E	Hornblende biotite schist
35- 1S-22E	No samples
4- 2S-23E	No samples
17- 2S-25E	No samples

Jerauld County:

9-107N-65W	Biotite muscovite adamellite
36- 1S-28E	No samples

Jones County:

2- 4S-28E	Granite
3- 1N-29E	Olivine gabbro
21- 2S-27E	No samples
15- 1N-29E	Sioix Formation
15- 3S-29E	No samples
8- 2N-26E	Sioux Formation
10- 1N-29E	Sioix
4- 3S-30E	Sioux Qtz.

Jones County (continued)

29- 2S-31E	Sioux Qtz.- No samples

Kingsbury County:

15-109N-54W	Quartz latite porphyry
24-109N-56W	Quartz latite porphyry

Lake County:

15-108N-54W	Questionable Precambrian; cuttings are heterogeneous

Lincoln County:

18-98N-49W	Sioux Formation
31-98N-51W	Sioux Formation
14-100N-49W	Sioux Formation

Lyman County:

24-101N-72W	No samples
6-104N-74W	Sioux Formation
16-104N-78W	Sioux Formation
22-105N-72W	Sioux Formation
4-103N-77N-	No samples-Sioux Formation

Marshall County:

19-126N-60W?	Muscovite biotite adamellite

McCook County:

34-102N-53W	Sioux Formation
27-102N-54W	Questionable Precambrian; cuttings are heterogeneous

Meade County:

19- 6N- 6E	No samples

Melette County:

23-43N-29W	
14-43N-29W	Sioux

Miner County:

16-105N-58W	Sioux Formation
2-106N-56W	Sioux Formation
30-108N-57W	Hornblende granite

Minnehaha County:

30-102N-48W	Sioux Formation (including pipestone layers)

Perkins County:

19-13N-16E	Muscovite biotite no samples adamellite
7-17N-15E	Muscovite biotite
13-20N-12E	Chlorite biotite adamellite
24-19N-16E	No samples

Potter County:

34-118N-78W	Layered biotite hornblende gneiss and biotite granite gneiss
27-119N-78W	Granofels

Roberts County:

18-127N-50W	Granite

Sanborn County:

21-108N-59W	Hydrothermally altered volcanic porphyry

Shannon County:

25-36N-48W	Gneissic biotite adamellite

Spink County:

18-114N-62W	Biotite granite overlain by probable Sioux Formation
26-115N-64W	Schist

Stanley County:

23- 3N-25E	Sioux Formation
9- 4N-27E	Sioux Formation
13- 5N-29E	Granite
36- 5N-27E	Sioux Formation
26- 5N-28E	Sioux Formation
18- 7N-28E	Granite
16- 6N-27E	Biotite muscovite granite
23- 7N-26E	Chlorite biotite granite
22- 8N-26E	Sioux Qtz. (?)
29- 8N-27E	Olivine pyroxenite
12- 9N-27E	Diorite
10- 4N-28E	Sioux Qtz.

Tripp County:

33-95N-77W	Biotite granite
5-96N-75W	Biotite adamellite
22-98N-78W	Muscovite biotite gneiss
11-102N-78W	Sioux Qtz.
25-99N-79W	Muscovite biotite granite
23-100N-77W	Cataclastic biotite adamellite
22-96N-79W	Granite 2950-70 No sample below 2970
33-99N-79W	No samples

Turner County:

8-97N-55W	Cuttings are too small to identify rock
13-99N-55W	Sioux Formation
32-100N-52W	Sioux Formation
34-100N-52W	Sioux Formation
18-100N-54W	Hornblende schist overlain(?) by Sioux Formation; schist may be glacial outwash

Union County:

18-90N-48W	Biotite adamellite
29-92N-49W	Granofels
25-93N-50W	Altered diabase

Walworth County:

14-121N-77W	Biotite schist
36-123N-76W	Chlorite biotite granite

Yankton County:

13-93N-56W	Granite(?)
10-95N-54W	Sioux Formation
29-96N-56W	Diabase and gabbro
12-93N-55W	

TENNESSE

Cumberland County:

Location	Rock Type
16- 7S-57E	Layered Gabbro and Troctolite

Davidson County:

Location	Rock Type
16- 3S-35E	Biotite leuco-granite

De Kalb County:

Location	Rock Type
25- 6S-44E	Sequence of Tuffaceous rhyolite, arkose and rhyolite tuff cut by diabase Unmetamorphosed

Fentress County:

Location	Rock Type
25- 2S-55E	Tonalite gneiss cut by diabase dikes

Gibson County:

Location	Rock Type
19- 5S- 6E	Altered rhyolite porphyry and few chips of Hornblende syenite

Giles County:

Location	Rock Type
4-15S-29E	Micrographic granite

Humphreys County:

Location	Rock Type
14- 6S-19E	Tuffaceous rhyolite porphyry Arkose(?)

Lake County:

Location	Rock Type
3- 4S- 1E	Basal Feldspathic sandstone with Lamprophyric intervals
21- 2S- 1E	Cambrian sandstone

Macon County:

Location	Rock Type
12- A-43E	Granite reported

Maury County:

Location	Rock Type
16-12S-28E	Rhyolite overlying biotite hornblende syenite

Pickett County:

Location	Rock Type
3- A-54E	Riebeckite Quartz syenite Unmetamorphosed

Rutherford County:

13-10S-37E	Three intervals: upper: Sericitized spherulitic rhyolite Middle: Altered unmetamorphosed diabase Lower: Fine-grained metamorphic rock derived from mafic or intermediate igneous rocks

Wilson County:

10- 7S-39E	Micrographic granite

TEXAS

Andrews County:

Location	Rock Type
2,A-55,PSL	Granite gneiss
13,A-38,PSL	Diabase
4,A-55,PSL	Biotite hornblende gneiss

Baylor County:

BBB&C,195,A 7013	Biotite argillite

Borden County:

40, 32, ELRR 10789	Biotite diorite

Brewster County:

8, 548, GH & SA	Hornblende biotite gneiss

Briscoe County:

58, B-3, BS & F	Basic scarn rock
155, G & M, GC & SF	Diabase
142, M-10, D&SE	Diabase

Carson County:

181, 3, I&GN	Granodiorite
109, 5, I&GN	Amphibolite
30, 4, I&GN	Gneissic diabase
50, 4, I & GN	Granite
3, B-4, H&GN	Rhyolite porphyry

Castro County:

12, 9T, T&NO	Diabase
132, M-6, SK&K	Rhyolite porphyry
43, 10-T, T&NO	Diabase

Collingsworth County:

4, 16, H &GN	Biotite-feldspar-quartz gneiss
113, 22, H&GN	Granite gneiss
13, 11, H&GN	Granite

Coke County:

1-A, 261, H&TCRR	Biotite granitic gneiss
2, 230 & 187 H&TC	Feldspar-quartz gneiss

Comanche County:

J. M. Gaiser Sur. No. 298	Biotite
Chas. Sargent Sur. No. 73	Muscovitic quartzite

Concho County:

Wilhelm Kramer Survey 309	Gneissic granite

Cooke County:

W. F. Shaw Survey A-1307	Quartzo-feldspathic schist
Phelps Survey A-821	Amphibolite
E. Daniel Survey H or A-293	Metabasic rock
John R. Davis Survey	Carbonate

Cottle County:

6-2-J. H. Gibson Sur. A-1366	Biotitic metagraywacke
35-B-J. H. Stephens Sur.	Hornblende-biotite granodiorite
39-B-J. H. Stephens Sur.	Biotitic metagraywacke
29-B-J. H. Stephens	Biotitic metagraywacke
22, B, J. H. Stephens	Epidote metagraywacke

Crosby County:

5, A. C. Meyer	Granite

Culberson County:

7, 80, PSL	Biotite schist and gneiss

Dallam County:

1, 1, L&GN	Rhyolite porphyry
16-50-H&TC	Granite
81-7-Cap Synd. S/D	Rhyolite porphyry
10-1-BS&F	Rhyolite porphyry

Deaf Smith County:

7, 2N,1E	Rhyolite porphyry
45, K5, GB&CNG	Microgranite prophyry

Dickens County:

5, W.C.- J.C. Keller Surv.	Chlorite-actinolite-epidote rock
262, 1, H&GN	Hornblende granodiorite
226, 1, H&GN	Granite
19, H, H&TB	Brecciated granite
2, 1, R. H. hanna Sur.	Biotite granite
John Gibson A-52	Granite
8, G, C. U.	Granite

Donley County:

46, 20, H&GN	Granodiorite
104, C-7, Hooper & Wade	Granite
39, C-3, AB&M	Rhyolite prophyry
140, E, D&P	Granodiorite gneiss
50, 20, H&GN	Biotite granite
12, 29, H&GN	Diabase

El Paso County:

31°52'30" N 106°30' W	outcrop Rhyolite porphyry

Fisher County:

9, T&P	Quartz-feldspar gneiss

Gray County:

9, 8, A. W. Wallace	Granodiorite
177, B-2, H&GN	Rhyolite porphyry
8, B2, H&GN	Granite
3, 1, BS&F	Granodiorite
66, 25, H&GN(?)	Amphibolite
99, B-2, H&GN	Diabase
119, B-2, H&GN	Granite
179, 2, I&GN	Granite, diabase
15, 1, ACH&B	Granitic rock
110, 3, GNRR	Granodiorite
110, 3, I&GN	Granite
107, 3, I&GN	Diabase, granodioritic gneiss
12, 3, L&GN	Cataclastic granite
7, C-2, CCSD & RGN	Quartz diorite

Hale County:

8, D-10, EL&RR	Rhyolite porphyry

Hall County:

34, A, AB&M	Metasediment

Hardeman County:

81, 11, W&NW RR 9280	Granite

Hartley County:

7, LE, G&M	Rhyolite porphyry
26, LTO, T&NO	Rhyolite porphyry
375, 41, H&TC	Rhyolite prophyry
375, 44, H&TC	Rhyolite porphyry
29, 21, CSC	Rhyolite porphyry
25, 7, EL&RR	Rhyolite porphyry
21,10 State Cap Lands	Granite, diabase

Hartley County (continued)

34, B-8, ELRR	Rhyolite porphyry
45, LE, G&M	Rhyolite porphyry
10, A1, PSL	Cloritized granite
29, 21, State Cap Lands	Metarhyolite and granite
28, 21, Cap. Sch. Lds.	Porphyritic granite
26, 13, CSS	Rhyolite porphyry
36, ITO, T&NO	Welded Rhyolite tuff
18, ITO, T&NO	Porphyritic rhyolite
16, 21, State Cap Lands	Metarhyolite porphyry
44, 16, CSS	Biotite granite
55, LE, G&M	Rhyolite porphyry

Hutchinson County:

14, 3, BS&F	Biotite granite

Jones County:

DeWitt CSL Surv. 125 Lot 7	Metarhyolite?
190, 1, BBB&C	Granite

King County:

148, F, H&TC	Gneissic granite
144, A, J. B. Rector Surv.	Granite
8, 2, C. L. Carter Surv.	Metagraywacke

Lamb County:

Labor 12, League 664	Rhyolite

Lubbock County:

51, A, HE&WT	Rhyolite porphyry
72, C	Micrographic granite

Mitchell County:

62, 25, T&PRR	Hornblende granite gneiss

Montague County:

S. Little	Diabase
Fielding-Seacrest	Diabase
J. L. Graham Survey	Granite

Moore County:

76, 018, D&P	Granite
183, 3, TT&NN	Rhyolite porphyry
J. W. Proctor	Chloritized granite
76, 2, G&M	Rhyolite porphyry

Motley County:

27, M	Graywacke and argillite
13, AB&M	Biotite metagraywacke
280, AS&F	Muscovite-quartz-feldspar schist diabase
5, MC, ML&C	Metarhyolite
2, C. J.	Metagraywacke, diabase, meta-argillite and spherulitic rhyolite?
7, 1-4, WTRR	Biotite granodiorite
7, 0/1, Sur 7 SF	Biotite granite
117 Gibson Sur	Felsite porphyry

Nolan County:

36, 20, T&P	Muscovite schist

Oldham County:

Lge 310 Cap Lds	Micrographic granite porphyry
64, 2, G&M	Rhyolite porphyry
Lge 304	Rhyolite porphyry
16, B-5, ELRR	Rhyolite porphyry
13, H-3, SCL	Granite diabase
36, H-1, TTRR	Rhyolite porphyry
40, H-3, SCL	Micrographic granite prophyry
71, GM-5, G&M	Rhyolite porphyry

Parmer County:

10, T4S, R4E	Diabase

Pecos County:

128, 10, H&GN	Microdiorite
2, 115, GC&SF	Hornblende diorite
123, 11, H&GN	Granite and diorite gneiss
10S, 10, H&GN	Granite

Potter County:

14, 3, G&M	Rhyolite porphyry
11, 34, EL&RR	Rhyolite porphyry
98,0-18, D&P	Biotite granodiorite
190, 2, AB&M	Rhyolite porphyry
207, A&BM	Granite
30, M-20, G&M	Rhyolite porphyry
99, 46, H&TC	Rhyolite porphyry
13, M20, G&M	Granite diabase
222, 2, AB&M	Rhyolite porphyry
31, 0-18, D&P	Diabase
28, 1, BS&F	Rhyolite porphyry

Presidio County:

17, 2, T&P	Granite gneiss
105, 3, D&PRR	Sheared granite gneiss

Randall County:

179, 6, I&GN	Rhyolite porphyry
180, 6, I&GN	Rhyolite porphyry
18, 8, I&GN	Rhyolite porphyry

Reagan County:

18, 6, University Lands	Biotite granite

Roberts County:

201, M-2, BS&F	Altered granitic rock

Sutton County:

53, 14, TWNGRR	Sheared leucogranite diabase
48, A, GWT&R	Granite
8, A, GWT&PRR	Biotite granite

Taylor County:

7, 2, T&NO	Biotite gneiss and amphibolite

Wilbarger County:

35, H&TC	Meta-arkose
31, 4, H&TC	Feldspathic biotite schist
2, 10, H&TC	Arkosic metagraywacke

Winkler County:

14, B-2, PLS	Granite gneiss

WEST VIRGINIA

Mason County:

Location	Rock Type
Clendenin District, 2.5 mi. 597 S/lat. 38°45' & 4.12 mi. W/long. 82°22'	Hornblende gneiss[1]

Wood County:

Location	Rock Type
SE (Marietta quadrangle)	Gneiss, amphibolite[1] Tonalite and granodiorite gneiss; basic amphibolite; minor syenite bands[2]

WISCONSIN

Location (City)	Rock Type
Baraboo	Quartzite
Barron	Quartzite or conglomerate
Black Creek	Granite under drift
Bloomer	Granite
Casco Junction	Granite
Clintonville	Granite under drift
Delavan	Quartzite? (doubtful)
Eleva	Basalt
Fond du Lac	Quartzite, slate, *etc*.
	Quartzite
	Slate
Friednship	Gneiss, granite
Gillett	Hornblende schist under drift
Green Bay	Granite
	Granite
	Granite
	Granite
	Schist
Hartford	Quartzite
	Quartzite
	Quartzite
	Quartzite
	Quartzite
Hubbleton	
	Slate, quartzite
	Slate, quartzite
	Dolomite, slate, schist quartzite
Hudson	Basalt
Jefferson	Quartzite
Jefferson Jct.	Granite
	Granite
Juneau	Quartzite
	Quartzite
	Quartzite
Kaukauna	Granite
Kewaskum	Quartzite
Wisconsin Dells (Kilbourn)	Basalt, etc.
La Crosse	Granite
Madison	Basalt
	Basalt
	Basalt
	Granite
	Basalt
	Schistose rhyolite
	Rhyolite
	Basalt
	Rhyolite
	Granite

Winsconsin (continued)

	Basalt
	Basalt
	Basalt
Marinette	Quartzite
	Granite
	Granite
Mather	
	Basalt
Mayville	Jasper
Mount Calvary	Quartzite or granite
Necedah	Granite
	Diorite
	Granite, diorite
	Diorite
	Quartzite, granite
Oconomowoc	Quartzite
Oil City	Granite
Oshkosh	Granite
	Granite
	Granite
Pewaukee	Granite
Portage	Rhyolite
Prairie du Sac	Granite
Pray	
	Iron formation and schist
Reeseville	Quartzite under drift
Sauk City	Granite
Stillwater, Minn.	Sandstone
Tomah	Gneiss
	Granite
Two Rivers	Quartzite
Watertown	Slate
West Bend	Chert?? (doubtful)
Waupun	Pegmatite
	Quartzite
Whitehall	Gabbro
Granton	Granite
Shennington	Granite
Wells, Mich.	Schist
Adams	Quartzite
Augusta	Granite
Black Creek	Granite
Brandon	Quartzite
Brothertown	Quartzite
Cambria	
Chetek	Granite
Crivitz	Greenstone under drift
DeForest	Granite
Eau Claire	Gneiss
Fort Atkinson	Granite
Hustisford	Quartzite
Menomonee Falls	Quartzite, granite
Oregon	Rhyolite

Winsconsin (continued)

Rosendale	Quartzite
St. Croix Falls	Basalt
Powers, Mich.	Marble
Stephenson, Mich.	Granite
Shell Lake	? (no sample)
Kimberly	Granite
Wilson	? (no sample)
Reaspur	? (no sample)
Coloma	Granite

WYOMING

Big Horn County:

Location	Rock Type
7- 57N-97W	Cataclastic granite
35-54N-94W	Granite

Carbon County:

Location	Rock Type
17-26N-80W	Granite
10-16N-84W	Biotite granite gneiss
11-26N-81W	Leucogranite
15-26N-78W	Granite
13-24N-80W	Granodiorite
27-17N-88W	Chlorite schist
4-27N-86W	Amphibolite, biotite diorite gneiss, diorite
14-20N-81W	Adamellite
2-17N-89W	Gneissic granite
8-13N-88W	Granite
10-12N-92W	Quartzite
34-25N-86W	Altered diorite

Converse County:

Location	Rock Type
29-31N-68W	Granite, diorite

Fremont County:

Location	Rock Type
9-42N-105W	No basement
24-27N-101W	Phyllite, meta-graywacke, chloritized diabase
22-31N-94W	Biotite-quartz-feldspar schist with minor amounts of pegmatitic (quartz, albite, biotite) material
19- 2N- 1W	Biotite-quartz-feldspar gneiss

Hot Springs County:

Location	Rock Type
14-44N-98W	Adamellite
19-46N-98W	Granite gneiss
12-43N-96W	Chlorite-feldspar-mica rock
36-43N-94W	Banded gneiss?

Johnson County:

Location	Rock Type
21-41N-81W	Meta-arkose over granite pegmatite

Natrona County:

Location	Rock Type
36-37N-82W	Porphyritic granite

Niobrara County:

10-37N-62W	Biotite schist
2-39N-61W	Biotite-feldspar-quartz schist

Park County:

33-58N-100W	Granite

Appendix 2. Abstract of Paper Presented at the 94th Annual Meeting of the Geological Society of America.

PRECAMBRIAN ROCKS IN THE SUBSURFACE OF KENTUCKY AND TENNESSEE

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New regional aeromagnetic and Bouguer gravity anomaly maps, 60 wells to basement, and 12 Rb-Sr and K-Ar age determinations indicate the presence of two and probably three Precambrian basement rock provinces in the subsurface of Kentucky and Tennessee. The western parts of both states are underlain mainly by a 1200-1500 m.y. anorogenic felsic igneous province that is characterized by relatively subdued anomalies and low magnetic gradients. Sparse well control indicates that the rock types include rhyolitic and trachytic volcanic rock, one-feldspar granite, and unmetamorphosed sedimentary rock. Eastern Kentucky and northeastern Tennessee are underlain by the subsurface Grenville Province which is associated with closely-spaces magnetic anomalies of relatively high amplitude. Rock types include medium-grade metamorphic rock, granite gneiss, two-feldspar granite, and anorthosite. The probable boundary between these two provinces is delineated by a sharp magnetic and gravity anomaly gradient that trends south-southwestward through the east-central part of the region. Other possible locations of the boundary may be interpreted from processed geophysical maps. The third probable basement rock province consists of mafic volcanic, intrusive, and associated felsic igneous rock that apprently accumulated in continental rift zones of unknown but probable Keweenawan age. Sedimentary rock also occurs in some of these rifts.

Rb-Sr and K-Ar ages determinations help define the age and extent of the provinces. Interpretation is complicated by the partial coincidence between the apparent ages of 800-1100 m.y. from the subsurface Grenville Province and 1000-1200 m.y. Keweenawan igneous activity.

Lidiak, E. B., R. E. Denison, W. J. Hinze, and M. Halpern, 1981, Precambrian rocks in the subsurface of Kentucky and Tennessee (abs.): Geol. Soc. Am. Abstracts with Programs, v. 13, p. 497.

Appendix 3. Abstract of Paper Presented at the Third Annual NASA Geodynamics Program Review

LITHOLOGICAL CHARACTERIZATION OF BASEMENT ROCKS IN THE CONTINENTAL INTERIOR OF THE UNITED STATES

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ABSTRACT

Rocks of the buried Precambrian crust in the continental interior of the United States and diverse in both age and type, ranging from more than 2.7 b.y. to less than 1.0 b.y. in age and from granulitic gneiss and granite-granodiorite to gabbro and basalt in rock type. Rocks of intermediate composition are rare. The oldest rocks occur in the eastern Dakotas and are clearly buried portions of the Canadian Shield; they are mainly greater than 2.5 b.y. old and some may be as old as 3.6 b.y. The central part of the region, including Nebraska, northern Missouri, and northern Kansas, is underlain by orogenic igneous and metamorphic rocks whose ages are mostly 1.6 to 1.8 b.y.; scattered anorogenic granitic plutons whose ages are about 1.4-1.5 b.y. are also known in this terrane.

The most distinctive feature of the continental interior is the great terrane of felsic igneous rocks that makes up the basement from western Ohio and central Wisconsin across southern Missouri and Kansas and into Panhandle and far western Texas. These rocks, which include abundant rhyolite and mesozonal and epizonal granitic bodies range in age from 1.5-1.2 b.y., with a general tendency for ages to decrease from northeast to southwest; older rocks are not known anywhere within this terrane. Toward the east in eastern Ohio, eastern Kentucky, and eastern Tennessee and toward the south in central Texas the basement terrane consists of medium-grade metamorphic rocks and associated granitic plutons that formed mainly 1.0 to 1.1 by.y. ago.

Basalt, interflow arkosic sedimentary rock, and related gabbro are associated with continental rift zones. The most prominent of these features is the 1.1 b.y. Keweenawan rift, extending from Lake Superior to Kansas, which is generally regarded as being an abortive-type continental rift structure. Geophysical and sparse basement well data suggest that other basaltic rift zones occur in the Michigan basin, Ohio, Kentucky, and Tennessee.

The region prior to about 1.6 b.y. ago was characterized by eugeosynclinal sedimentation and orogenic tectonic styles. Stabilizing of the continental interior was reflected in the deposition of orthoquartz sandstone beginning about 1.6 b.y. ago. Subsequent igneous activity, sedimentation, and tectonics were dominantly anorogenic except for orogenic events and sedimentation along the margins of the stable interior.

Lidiak, E. B., 1981, Lithological characterization of basement rocks in the continental interior of the United States (abs.): Third Annual NASA Geodynamics Program Review, Goddard Space Flight Center, p. 36.

Appendix 4. Expanded Abstract of Paper Presented at the Fifty-Second Annual International Meeting of the Society of Exploration Geophysicists.

RELATION BETWEEN DRILL-HOLE BASEMENT LITHOLOGY AND MAGNETIC AND GRAVITY ANOMALIES IN THE EAST-CENTRAL MIDCONTINENT

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Regional aeromagnetic anomaly and Bouguer gravity anomaly maps are widely used in conjunction with samples from deep drill holes to basement to interpret the tectonic development of the buried basement and to construct basement rock maps. However, little emphasis has been given thus far to detailed study of the relation between the lithology and physical parameters of buried basement rock samples and the magnitude and amplitude of magnetic and gravity anomalies that occur in the immediate vicinity of the drill holes to basement. For this reason a study was undertaken to determine just how accurately samples from the basement reflect the magnetic and gravity signatures and to evaluate the factors that lead to ambiguities in correlation. Wells to basement were plotted according to rock types on recently compiled aeromagnetic and long wavelength cut Bouguer gravity anomaly maps of the east-central midcontinent, and anomaly values coinciding with each well location were determined.

In general, there is rather poor correlation between rock type and both magnitude of total intensity magnetic anomalies and Bouguer gravity anomalies (100-8 km band-passed data). There is, however, some tendency for mafic igneous rocks to coincide with positive Bouguer anomalies and for felsic intrusive rocks and granitic gneisses, although variable, to be associated with lower Bouguer values. Similarly, the magnetic susceptibility of basement samples plotted against total magnetic intensity shows no clear distinction among the main rock types. Metamorphic rocks do display a good positive correlation of these two parameters for most samples, as do, to a lesser extent, felsic igneous rocks and possibly mafic igneous rocks. The causes of the generally poor correlations are varied and include such factors as the drill hole not encountering the main causative anomaly both laterally and at depth, general basement inhomogeneity, physical properties inhomogeneity, basement layering, sample alteration, and lack of definitive geophysical properties.

The correlations can best be assessed on a series of diagrams. Figure 1 shows that there is considerable overlap in total intensity magnetic values for all the main rock types. Mafic intrusive rocks occur in areas of higher magnetic intensity but, suprisingly, mafic extrusive rocks do not. Considering metamorphic rocks, which include both low and medium metamorphic grades and mafic and silicic compositions, there is no relation to grade of metamorphism or composition. Also surprising is the fact that most felsic intrusive rocks occur in areas of relatively high magnetic intensity.

Figure 2 indicates that there is also wide variation in Bouguer gravity anomalies (100-8 km band-passed data) associated with all the main rock types. Both extrusive and intrusive mafic igneous rocks occur in areas of higher Bouguer gravity values. Of the metamorphic rocks, two amphibolites

reflect higher Bouguer anomalies than lower grade rocks and more silicic compositions. The felsic extrusive and intrusive igneous rocks occur in areas of widely different Bouguer gravity anomalies, although many of the rocks do occur in areas of generally lower intensity anomalies than do the mafic rodks. The occurrence of about one-half of the felsic igneous rocks in areas of higher anomalies is clear indication that additional causative factors contribute to the gravity anomalies.

On Figure 3 are plotted by rock type the total intensity magnetic anomalies versus 100-8 band-passed Bouguer gravity anomalies. As with the previous figures, there is considerable overlap in geophysical anomalies among the rock types. Mafic igneous rocks occur in areas of consistently high gravity anomalies (0 to +11 mgal) but of wide variation in magnetic signature. Felsic volcanic rocks similarly occur in areas having widely different magnetic intensities. Gravity anomalies for most of these volcanics cluster at about 0 mgal. Felsic intrusive rocks show the greatest variation in gravity anomalies, most samples occurring between -10 and +10 mgal. These rocks also display a crude positive correlation between gravity and magnetic intensities. Metamorphic rocks also vary considerably, particularly in magnetic intensity. Most granitic gneisses occur in areas containing gravity anomalies between 0 and -10 mgal. Most mafic schists, both low and medium metamorphic grade, occur in areas of 0 to +6 mgal values.

Magnetic susceptibility measurements were carried out on basement rock samples from the study area. The results, plotted against total intensity magnetic anomalies, are shown on Figure 4. Each rock type shows considerable variation within groups and overlapping values among groups, making characterization difficult. A major feature on Figure 4 is the excellent positive linear correlation of six of the eight metamorphic rocks. Such correlations are expected if the measured sample is representative of the basement rock body in place and if the total intensity magnetic value accurately reflects that boyd. Felsic igneous rocks show some tendency toward a broad, poorly defined positive correlation. Mafic igneous rocks may show a similar trend, but data points are too few to be definitive. Felsic volcanic rocks show no direct relation between the two plotted parameters.

The reasons why the rocks do not display distinc magnetic and gravity signatures or magnetic susceptibility contrasts are varied. It must be kept in mind that rocks are not classified on the basis of susceptibility and density, and thus 1:1 correlation should not be expected. This commonly results in contrasting rock types not having definitive geophysical signatures. There are other important factors as well. The geophysical maps used in this study are regional maps and record anomalies at a larger scale than the individual drill hole localities. Thus, the drilled sample may have missed laterally the body causing the anomaly, or the drill may not have penetrated deeply enough into the basement to encounter the causative body. Depth to basement is a clearly related factor. In this area of the east-central midcontinent (Kentucky, Tennessee, southern Indiana, and southern Illinois), the basement typically is buried to a depth of 5000-10,000 ft. Another factor is basement and physical properties inhomogeneity. This is a particular problem in steeply dipping rock bodies and gneissic complexes. Flat-lying layered bodies or surface alteration can also result in the recovered basement rock not accurately reflecting

the body that produced the observed anomaly. Finally, it must be kep in mind that filtered or derivative geophysical maps can create apparent anomalies that are not related to basement features. A consideration of the various factors discussed here is a clear indication that considerable caution needs to be exercised in comparing geophysical data with basement rock samples obtained from widely separated drill holes.

Lidiak, E. G., and W. J. Hinze, 1982, Relation between drill-hole basement lithology and magnetic and gravity anomalies in the east-central midcontinent (abs.): Soc. Expl. Geophys. Technical Program Abstracts and Biographies, p. 258-260.

Appendix 5. Expanded Abstract of Paper Presented at the Fifty-Second Annual International Meeting of the Society of Exploration Geophysicists.

GEOLOGIC SIGNIFICANCE OF REGIONAL GRAVITY AND MAGNETIC ANOMALIES IN THE EAST-CENTRAL MIDCONTINENT

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Recently compiled Bouguer gravity and magnetic anomaly maps of the east-central Midcontinent covering the area approximately between 35° - 39°N latitude and 82° - 92°W longitude provide the opportunity to study the tectonic framework of the basement rocks which lie buried beneath generally low-dipping Phanerozoic sedimentary rocks. A variety of wavelength filters, including continuation, wavenumber, derivative, and directional filters, are useful in isolating and identifying particular attributes of anomalies associated with the basement rocks. These maps in conjunction with lithologic information and isotopic age dates obtained from the few widely distributed drill holes which reach the basement rocks are used to define four principal basement zones. The southeastern corner is marked by long, linear northeast-striking anomalies which correlate with Appalachian Mountain structural trends. Immediately to the west are the more northerly trends of the subsurface continuation of the Grenville province. West of the Grenville front, which is poorly defined in Tennessee, lies the roughly 1500 Ma felsic basement rocks of the Central province. A generally subtle, west-northwest pattern of anomalies pervades the Central province probably due to a more ancient basement which underlies the felsic rocks. Transecting this region is a series of parallel correlative gravity and magnetic anomalies which are interpreted to mark the margins of a late Precambrian rift complex centered over the confluence of the Mississippi and Ohio Rivers.

A critical element of the New Madrid Seismotectonic Study Program sponsored by the U. S. Nuclear Regulatory Commission is the investigation of the tectonic framework of basement rocks of the east-central Midcontinent. Identification of the tectonic elements of the basement rocks and in particular the potential zones of weakness is useful in characterizing potential earthquake hazards especially when combined with information on the prevailing stress field and seismicity of the region. To study the basement rocks, Bouguer gravity (Figure 1) and total intensity magnetic anomaly (Figure 2) maps have been prepared of Tennessee, Kentucky, and portions of adjoining states.

Gravity observations were made in selected areas to supplement existing data coverage to obtain stations along existing roads at roughly a 2 km interval. The resulting file of approximately 50,000 gravity measurements tied to the IGSN-71 gravity datum were reduced to simple Bouguer anomaly values using a sea level datum, a reduction density of $2.67 g/cm^3$, and the 1967 theoretical gravity formula.

The total intensity magnetic anomaly map was compiled from 28 aeromagnetic surveys by visual comparison and manual adjustment of adjoining anomaly maps. The surveys were generally flown along roughly 2 km flight

paths at a mean elevation above the surface of approximately 300 m. The core derived magnetic field was removed from the observations by subtracting an appropriate, updated geomagnetic reference field. All data were adjusted upward by 1000 gammas (nT) to minimize the occurrence of negative contour values.

Both the gravity and magnetic observation data sets were gridded on a registered 2 km orthogonal array. This grid was used for hand contouring the gravity anomaly map, machine contouring the magnetic map, and wavenumber filtering both data sets. The magnetic anomaly data were reduced-to-pole to eliminate the effect of inclined induced magnetization, and both data sets were selectively band-pass, high-pass, and low-pass filtered, upward continued, and subject to derivative and strike-reject and strike-pass filtering to emphasize particular characteristics of the anomaly fields. An example of these filtered maps is shown in Figure 3 which was prepared by passing gravity anomaly wavelengths between roughly 8 to 100 km. This map isolates the local gravity anomalies within the upper crust from the broad positive gravity anomaly over the Mississippi Embayment and the regional negative anomaly associated with the Appalachian Mountains. The filtered maps are primarily useful for qualitative analysis, in identifying and extending subtle anomalies through areas of complex and conflicting patterns, in isolating anomalies from either longer or shorter wavelength anomalies, and in modifying anomaly data to enhance the correlation of the gravity and magnetic anomaly fields.

The gravity anomaly map is dominated by a broad positive feature, locally reaching absolute amplitudes in excess of +25 mgal associated with the Mississippi Embayment and negative values of less then -100 mgal related to the Appalachian Mountains. Upon removal of these long wavelength components of the gravity field, four basic anomaly patterns emerge (Figure 3). Interpretation of the geologic significance of these patterns is assisted by lithologic information and isotopic age dates obtained from basement rock samples retrieved from widely separated deep drill holes. Several basement geologic provinces are evident in the gravity and associated magnetic anomalies.

Northeast striking elongate gravity and magnetic anomalies in the southeast corner of the map (Figures 2, 3) parallel the structural trends of the Appalachian Mountains. This pattern is terminated abruptly along a northeast line passing through Knoxville and Chattanooga, Tennessee. West of this line the major gravity anomalies are positive and strike roughly north-south. The magnetic anomalies associated with the positive gravity features exhibit a "birds-eye" pattern of intense positive amplitude. This zone is identified as a continuation of the roughly 1000 Ma Grenville province which crops out in the Canadian shield. The western margin of this province, (Figure 4) the Grenville front, is placed along the western limit of the most prominent of the northerly striking anomalies with the aid of geologic information from basement drill hole samples. The intense gravity anomalies which occur along the Grenville front are interpreted as originating from metamorphosed mafic igneous rocks that may be a relic of a rift system extending south from Ohio into Kentucky and Tennessee. West of the Grenville front, the basement consists largely of felsic rocks of the roughly 1500 Ma Central province. Sporadic basalts occur within this granite/rhyolite terrane.

A west-northwest pattern of gravity and magnetic anomalies pervades the Central province. Generally this pattern is rather subtle, but a major anomaly having this trend strikes across the southern tip of Illinois into Missouri as well as into Kentucky and on into Tennessee. This pattern of anomalies may reflect petrologic variations in a more ancient basement which underlies the felsic rocks of the Central province. Transecting this province is a series of parallel, northeast-striking correlative gravity and magnetic anomalies which are interpreted to mark the margins of a late Precambrian rift, the Reelfoot rift, which was reactivated in Mesozoic time and is currently the site of the most intense seismicity in the Midcontinent, the New Madrid seismic zone. This feature splits into a series of rift arms (Figure 4) near the confluence of the Mississippi and Ohio Rivers. The series of structural features observed in the Phanerozoic sedimentary rocks along the 38th parallel of latitude and commonly referred to as the 38th-parallel lineament may be the result of reactivation of east-west trending faults of the New Madrid rift complex and the Rome trough which lie roughly along the 38th parallel.

Hinze, W. J., E. G. Lidiak, J. E. Reed, G. R. Keller, L. W. Braile, and R. W. Johnson, 1982, Geologic significance of regional gravity and magnetic anomalies in the east-central midcontinent (abs.): Soc. Expl. Geophys. Technical Program Abstracts and Biographies, p. 264-266.

Appendix 6. Abstract of Paper Presented at the 17th Annual North-Central Section Meeting of the Geological Society of America.

CHEMICAL COMPOSITION OF PRECAMBRIAN ROCKS FROM THE SUBSURFACE OF OHIO

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Major element analyses on glasses from 37 basement samples from the Precambrian of Ohio have been determined by microprobe techniques. Samples are from unmetamorphosed and metamorphosed basement terranes which are separated by a proposed tectonic boundary that trends south through west-central Ohio. Preliminary study reveals no systematic chemical variation among rock types. However, the chemical data form the basis for additional characterization of the terranes.

Volcanic rocks analyzed from western Ohio consist of trachyte, rhyolite, and basalt. The trachytes contain altered orthoclase or microcline microphenocrysts and hornblende pseudomorphs in a matrix of feldspar, opaques, zeolite, and abundant chlorite. They are metaluminous to peraluminous, have SiO_2 contents between 57% and 62% and high K_2O/Na_2O ratios. The rhyolites contain quartz microphenocrysts in a matrix of quartz, altered feldspar, and opaques. They are peraluminous, have SiO_2 contents between 67% and 72% and also have high K_2O/Na_2O ratios. Moderate alteration displayed by both rock groups and high K O/Na O ratios suggest that the present chemistry does not reflect primary igneous compositions. The basalts (46-50% SiO_2) are plagioclase phyric and contain matrix plageoclase, augite, and opaques. Both alkaline and subalkaline varieties are present.

Amphibolites in central and eastern Ohio have SiO_2 contents between 51% and 55% SiO_2, low FeO and MgO, high CaO and Al_2O_3, and Na_2O/K_2O ratios greater than 1. They mainly have subalkaline affinities. Biotite and hornblende granite and granitic gneiss in the same terrane exhibit similar mineralogy and chemistry. SiO_2 ranges from 65% to 74% and they are peraluminous or metaluminous. Coarse grain size and very high K_2O/Na_2O ratios suggest that some of the analyses may not be representative.

Ceci, V. M., and E. G. Lidiak, 1983, Chemical composition of Precambrian rocks from the subsurface of Ohio (abs.): Geol. Soc. Am. Abstracts with Programs, v. 15, p. 216.

Appendix 7. Abstract of Paper Presented at the 96th Annual Meeting of the Geological Society of America.

TECTONIC FRAMEWORK OF BASEMENT ROCKS IN THE EASTERN MIDCONTINENT

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The Precambrian in the subsurface of the eastern Midcontinent consists of four major basement provinces which can be delineated by regional geophysical, lithologic, and isotopic data. Recently compiled Bouguer gravity and magnetic anomaly maps, along with a variety of derived geophysical maps, are particularly useful in showing the extent and characteristics of basement provinces, establishing regional structural trends, and in correlating basement rock types with specific anomalies.

The oldest rocks occur in the westen part of the region which is underlain by approximately 1500-Ma-old anorogenic felsic igneous rocks. Widespread but generally subtle WNW-trending geophysical anomalies associated with much of this province are attributed to an older (lower Proterozoic?) basement that underlies the felsic igneous rocks. Less extensive NE-trending anomalies in the eastern part of the province have a probable similar deep source. Superimposed on these anomalies and transecting the region are correlative gravity and magnetic anomalies that outline a series of probable late Proterozoic rift complexes in which both basaltic igneous and clastic sedimentary rocks accumulated. The subsurface Grenville Front marks the present eastern boundary of the Central Province. East of the front are prominent north-trending anomalies of the subsurface Grenville Province. The metamorphosed mafic igneous rocks which are probable relicts of portions of the late Proterozoic rift complexes. To the east the Precambrian trends change to linear NE-trending anomalies paralleling the Appalachina orogenic belt. These anomalies probably reflect deep Appalachian structures.

Lidiak, E. G., V. M. Ceci, W. J. Hinze, and J. P. McPhee, 1983, Tectonic framework of basement rocks in the eastern midcontinent (abs.): Geol. Soc. Am. Abstracts with Programs, v. 15, p. 627.

Appendix 8. Abstract of Paper to be Presented at the 15th Annual North-Central Section Meeting of the Geological Society of America.

SPECULATIONS ON RIFT ZONES AND BASALTIC MAGMATISM IN THE PRECAMBRIAN OF THE EAST-CENTRAL MIDCONTINENT

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Rift zones and associated basaltic rocks are probably more common in the basement of the east-central Midcontinent than generally envisaged. They are important because they provide clues to the Precambrian tectonic development of the region. The Mid-Michigan anomaly is a generally accepted rift that trends northwest through the Michigan Basin and is associated with linear gravity and magnetic highs. A single deep well into this rift zone encountered arkose underlain by basalt. The basalt has affinities to intraplate tholeiites which is consistent with a continental rift setting. A second rift zone also trends northwest through western Ohio and northeast Indiana and subparallels the Mid-Michigan rift. Gravity and magnetic highs also coincide with this feature. Eight wells to basement along this proposed rift encountered basalt or gabbro, the least altered of which have major element compositions consistent with their being continental tholeiites. A more problematic rift occurs farther south in eastern Kentucky where the linear east continent gravity high has a northerly trend. Magnetic highs coincide in part with this anomaly, but are more extensively developed. This zone can be interpreted as a rift; however, the presence of the Grenville Front immediately to the west and the sparse wells to basement which encountered hornblende or chlorite schist and felsic metavolcanic rock lead to alternative interpretations. About 100 km to the west is a second north-trending gravity high which may also be a rift. The more extensive and complex ameboidal magnetic anomalies suggest, however, the possible presence of a plateau-like volcanic field. A single well to basement encountered a rhyolite. Other rifts have been proposed, for example, in western Ohio and western Indiana, but their presence remains highly speculative.

Lidiak, E. G. and W. J. Hinze, 1984, Speculations on rift zones and basaltic magmatism in the Precambrian of the east-central midcontinent (abs.): _Geol. Soc. Am. Abstracts with Programs_.

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Basement Rocks of the Main Interior Basins of the Midcontinent

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ABSTRACT

The basement underlying the deeper basins in the Midcontinent is not well known because of the considerable thickness of overlying sedimentary rocks However, gravity and magnetic surveys and sparse wells to basement suggest that deeper intracratonic basins are characteristically underlain by denser and more magnetic rocks than in adjacent areas This correlation has important bearing on understanding the tectonic development and geologic history of Midcontinent basins

The Michigan basin is underlain by prominent, linear gravity and magnetic highs that extend across the southern peninsula A recent deep well to basement encountered basalt overlain by red clastic sedimentary rock The combined geophysical and geological data support the idea that the basin is underlain by a Precambrian rift zone The Illinois basin also contains prominent gravity and magnetic anomalies The broad anomalies do not appear to correlate with any specific rock type at or near the top of the basement and may instead reflect intrabasement variation, such as major tectonic boundaries The more local, closely spaced anomalies outline a complex reactivated rift zone that trends generally northeast through the deepest part of the basin The Williston basin is another deep basin that is underlain by a linear gravity high The gravity anomalies continue into Canada where they are associated with granulites and major fault zones that occur near the boundary between the Superior and Churchill provinces The few wells to basement in the deeper parts of the Williston basin along the gravity high encountered granulites and other high-grade metamorphic rocks, suggesting that a major tectonic boundary similar to that occurring in Canada is present in the basement underlying the basin The Forest City and Salina basins contain less distinct gravity highs which occur on opposite sides and are partly obscured by the well known Midcontinent gravity high and rift zone The remaining basin under discussion the Arkoma basin differs from those previously discussed in that it contains a large gravity low, which probably reflects the development of an extremely thick section of sedimentary rocks along the Ouachita structural belt The Arkoma is, thus more comparable to the Appalachian basin than to the other basins, which are totally within the craton

The basins of the Midcontinent have apparently not all had the same tectonic development and are probably more complex than generally envisioned A generalization which appears to be a useful working hypothesis is that intracratonic basins of the continental interior differ from foreland basins and originated by reactivation of older structures during periods of extensional tectonism Consideration of basin development should take into account the Precambrian as well as the overlying Phanerozoic rocks

INTRODUCTION

The origin and development of basins have long been an intriguing problem in the geology of continents In general, the deep structures, rock units, and early history are particularly obscure Work initiated by Muehlberger and others (1967) on general basement rock studies in the Midcontinent suggested that basins are different from arches and plains Little direct knowledge on the lithology of the basement underlying the basins was available in this early study Direct sampling of the basement in the deeper basins is still extremely limited However, the increasing availability of regional and more detailed gravity and magnetic maps, seismic profiles, and geologic data provide a basis for interpreting the development of Midcontinent basins

The purpose of this paper is to discuss the Precambrian framework of the Michigan Illinois, Williston, Salina-Forest City, and Arkoma basins, to categorize basins according to type that occur in the Midcontinent and immediately adjacent areas to contrast intracratonic basins from foreland basins and aulacogens, and to discuss the possible origin of intracratonic basins of the Midcontinent

The location of the main basins in the general area of the Midcontinent is shown on Figure 1

Acknowledgments This report was supported by National Aeronautics and Space Administration Grant Number NSG-5270 The author expresses his appreciation to Herman H Thomas for his interest and cooperation Thomas H Anderson reviewed the manuscript Discussion with David Baker on the Williston basin is gratefully acknowledged The paper is dedicated to the memory of my wife, Fran

MICHIGAN BASIN

Structural Framework

The Michigan basin is a prominent and well-documented cratonic basin that occupies the southern peninsula of Michigan It contains an estimated maximum thickness of more than 15,000 feet of Phanerozoic sedimentary rocks that accumulated during subsidence dominated by flexure rather than by faulting (Cohee, 1945, Hinze and

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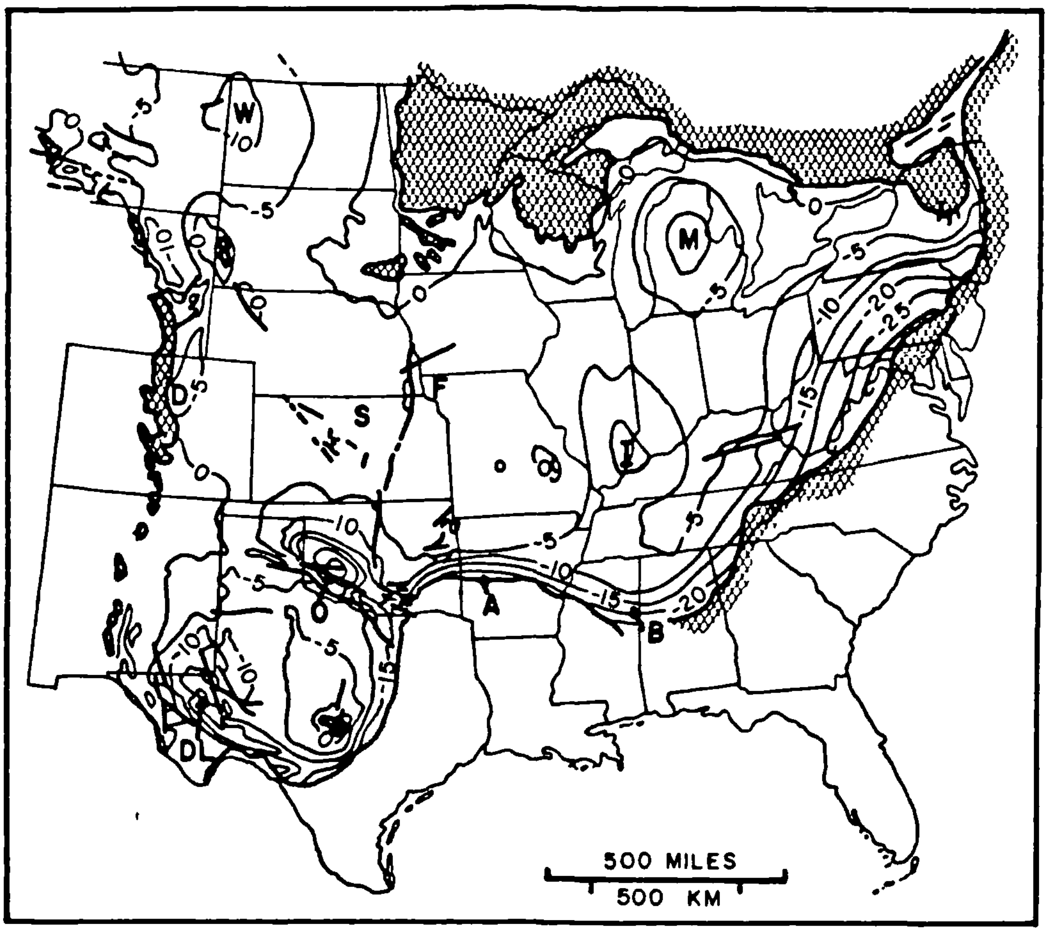

Fig 1 Distribution of basins in the Midcontinent region, United States Contours are in thousands of feet on the buried basement surface Basin abbreviations A - Arkoma, B - Black Warrior, DL - Delaware, D- Denver, F - Forest City, I - Illinois, M - Michigan, O - Southern Oklahoma, S - Salina, W - Williston Exposed Precambrian, cross-hatched pattern Ouachita system dotted pattern Adapted from Flawn (1967)

others, 1975, Sleep and Sloss, 1978) The Precambrian basement underlying these cover rocks is broadly oval in outline with little or no small-scale topographic relief (Fig 2)

Basement Rocks and Regional Geophysics

Limited samples are available from the basement, which has been penetrated by a total of 22 wells Most wells are in the southeastern part of the basin where depth to basement is generally less than about 7,000 feet As a consequence, regional geophysical studies, mainly gravity and magnetic surveys, are the main source of information on the lithology and structure of the basement The Michigan basin is an excellent example of the combined use of regional geophysical and limited basement well data in interpreting basement geology

The main geophysical feature of the Michigan basin is a prominent linear Bouguer gravity (Fig 3) and magnetic high that trends north to northwest across the southern peninsula (Hinze, 1963, Hinze and others, 1975) The magnitudes of these anomalies clearly indicate that they originate from lithologic and structural variations in the basement rather than from sources in the overlying sedimentary rocks Hinze and co-workers (Hinze, 1963, Oray and others, 1973, Hinze and others, 1971, 1975) have correlated these anomalies with middle Keweenawan basalts and associated upper Keweenawan clastic sedimentary rocks and postulated that the rocks accumulated in a continental rift zone of Keweenawan age, similar

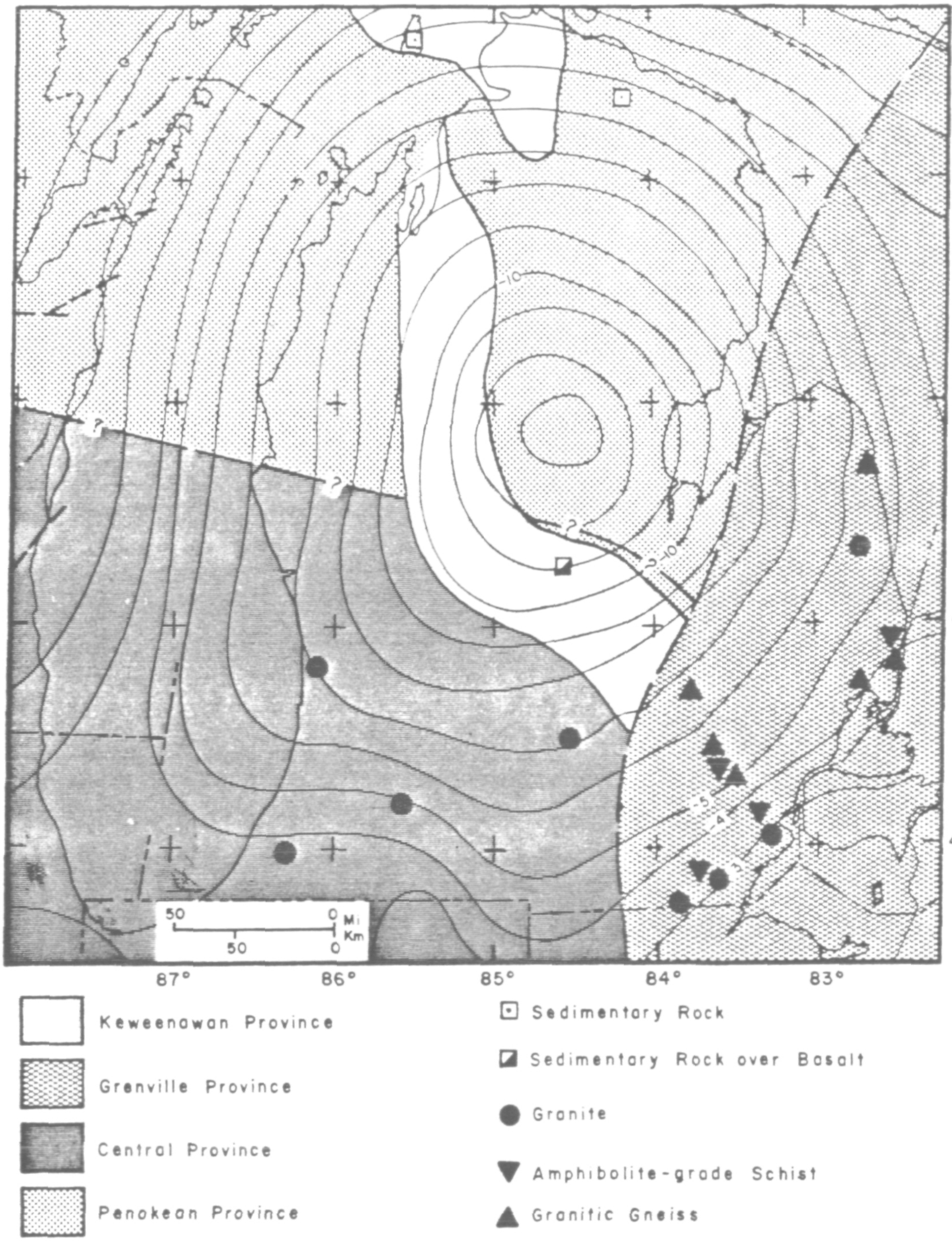

Fig. 2. Geologic map of basement rocks in the Michigan basin. Basement configuration contours, in thousands of feet, from Bayley and Muehlberger (1968).

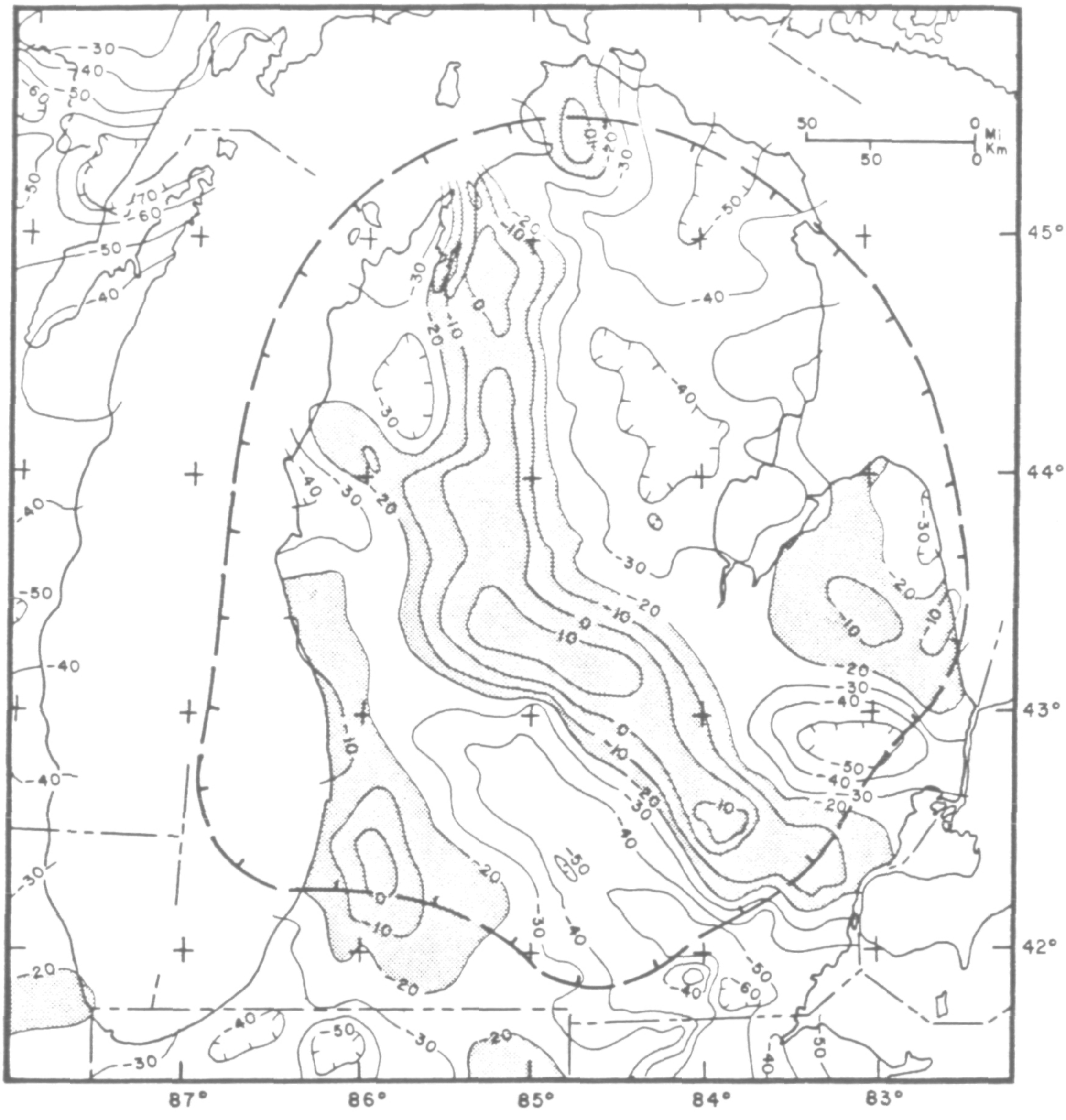

Fig. 3. Bouguer gravity map of the Michigan basin. Contour interval is 10 mgal. From Am. Geophys. Union and U.S. Geol. Survey (1964). Gravity highs - stippled pattern. Dashed hachure line outlining the Michigan basin is the -5,000 ft. contour of Figure 2.

to the rift that developed along the Midcontinent gravity anomaly (King and Zietz, 1971; Ocola and Meyer, 1973).

The main basement provinces and the lithology of available basement well samples are shown on Figure 2, which is adapted from Hinze and others (1975). Recent wells to basement have been added. Delineation of the provinces is based on lithology of basement well samples, isotopic ages, and extrapolation of geologic trends from the exposed Precambrian shield to the immediate north and west of the Michigan basin. Four main provinces are recognized. The presence of the oldest province, the Penokean province, in the northern part of the basin is based entirely on extrapolation of geophysical and structural trends. Inferred rock types are mainly metasedimentary rocks, metavolcanic rocks, and gneisses. These rocks were

probably deformed and metamorphosed 1600-1800 m.y. ago, during the Penokean orogeny.

The Central province occupies the southwestern part of the basin, and is widespread in the northern and eastern Midcontinent of the United States (Lidiak and others, 1966). The main rock types consist of granite, rhyolite, and related rocks; metasedimentary rocks and gneisses are subordinate. Isotopic ages in the range of 1200 m.y. to 1500 m.y. have been obtained on samples from adjacent areas.

The third province, the Keweenawan province (1050-1150 m.y.), coincides with the prominent gravity (Fig. 3) and magnetic anomalies that transect the Michigan basin. A recent deep drillhole on the gravity anomaly in Gratiot County, Michigan, encountered pre-Mt. Simon (Upper Cambrian) lithified red mudstone and interbedded arkosic sandstone underlain by coarsely ophitic metabasalts (Sleep and Sloss, 1978; McCallister and others, 1978; Fowler and Kuenzi, 1978). Two other deep wells on Beaver Island in Lake Michigan on the western flank of the linear gravity anomaly also encountered a similar red-bed sequence (Fowler and Kuenzi, 1978). The pre-Mt. Simon rocks in these three wells are strikingly similar to the middle Keweenawan basalts and upper Keweenawan sedimentary rocks of the Lake Superior region. The combined geological and geophysical data thus strongly suggest the presence in the Michigan basin of Keweenawan-age rift zone.

Grenville-like rocks compose the fourth province, which extends southwestward from the Canadian Shield across the eastern margin of the basin and continues southward into Ohio. The province is characterized by medium- to high-grade metamorphic rocks, gneisses, and granites. Anorthosites and calc-silicate rocks are present locally. Prominent gravity and magnetic anomalies parallel the Grenville trend along most of its extent. The youngest major period of metamorphism and igneous activity occurred about 1100 m.y. ago. K-Ar and Rb-Sr ages of 800-1100 m.y. on micas reflect later tectonic or thermal disturbance and probably deep burial and subsequent uplift. An important aspect of the Grenville front in this region is that the front appears to crosscut the Keweenawan rift zone. Hinze and others (1975) have noted that there is no correlative positive magnetic anomaly associated with the southeast-trending gravity anomalies east of about longitude 83°45'W, which is near the boundary between these two provinces. The absence of a magnetic anomaly suggests that basalt is not present at or near the basement surface east of this boundary, probably because of erosion and uplift during Grenville orogenic activity. The eastward continuation of the gravity feature is attributed to an intrabasement anomaly, perhaps reflecting metamorphosed Keweenawan mafic intrusive rocks at depth.

ILLINOIS BASIN

Structural Framework

The Illinois basin occupies most of southern and central Illinois and adjacent parts of Indiana, Kentucky, and Tennessee. The basin is moderately elongate in a north-northwestern direction and is bounded by the Ozark uplift to the west, the Pascola arch to the south, and the Nashville dome to the east. The basin has a maximum depth of about 15,000 feet in southern Illinois (Fig. 4).

Complex structures occur in the deeper parts of the basin at the intersection of the extension of the New Madrid seismic zone and the 38th-Parallel lineament (Heyl, 1972; Braile and others, in press). This region is centered on the most intensely faulted area in the central cratonic United States. The other major structure in the basin is the La Salle anticlinal belt, the western edge of which is a monocline that slopes steeply westward (Wilman and others, 1975). Many smaller structures are present throughout the basin.

Basement Rocks and Regional Geophysical Setting

Approximately 18 wells have been drilled to basement or to pre-Mt. Simon (Upper Cambrian) sedimentary rocks in the general area of the Illinois basin. Their distribution and lithology are shown on Figure 4. The main rock types are granite, rhyolite, trachyte, basalt, and unmetamorphosed sedimentary rock. The felsic igneous rocks are petrographically similar to the granites, rhyolites, and trachytes of the St. Francois Mountains, which formed 1400-1500 m.y. ago. These rocks are part of a great elongate northeast-trending anorogenic felsic igneous province that is extensively developed in the central craton of the United States (Engel, 1963; Goldich and others, 1966; Lidiak and others, 1966; Muehlberger and others, 1966, 1967; Silver and others, 1977; Emslie, 1978; Denison and others, in press).

Regional geophysical anomalies indicate that dense and magnetic rocks are also common at the basement surface or in the basement infrastructure beneath the Illinois basin. A Bouguer gravity map of the basin (Fig. 5) shows a broad high that has a regional northwest trend and along which occur more local highs. Similar trending aeromagnetic anomalies are also present (Lidiak and Zietz, 1976). More detailed maps (Braile and others, in press) confirm these anomalies, show

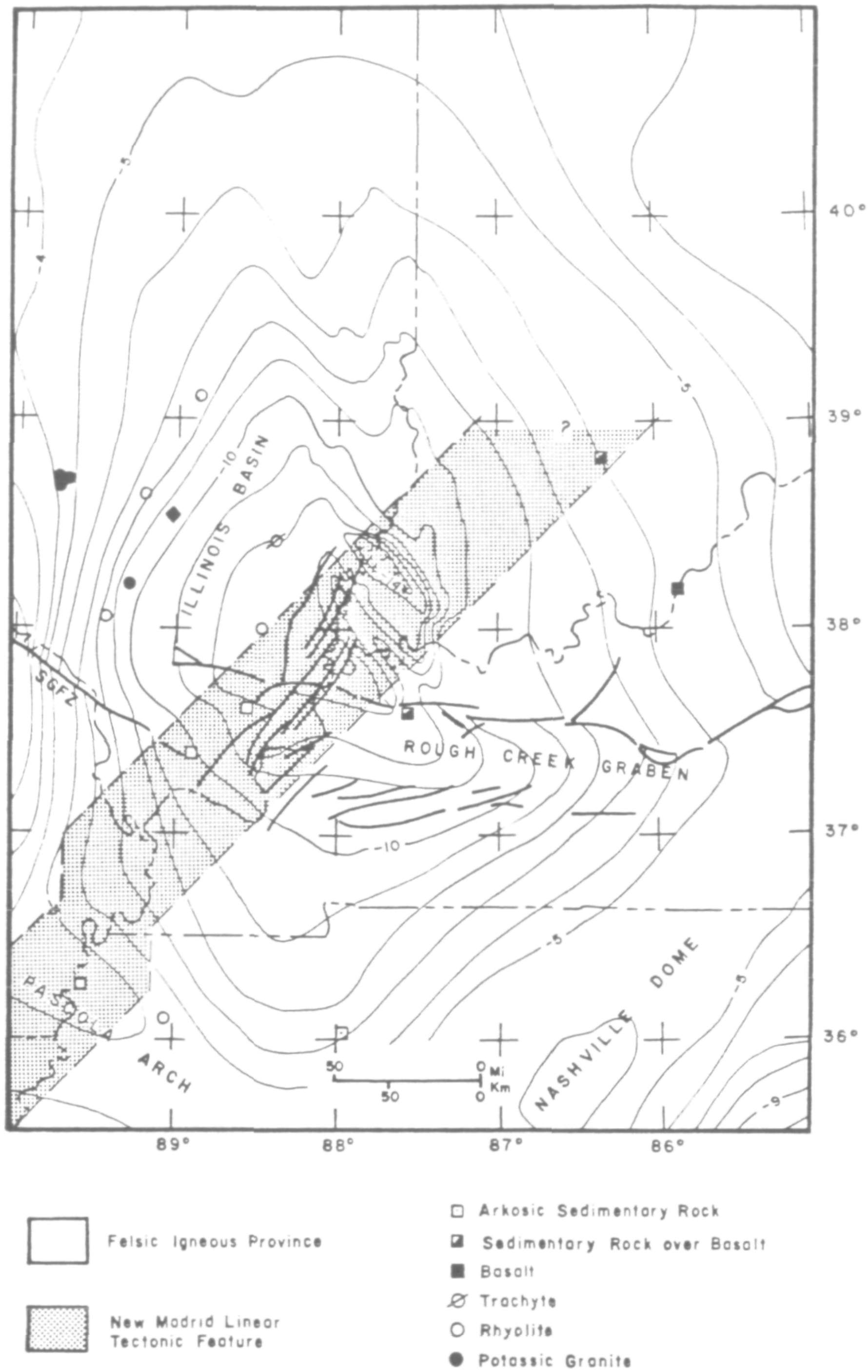

Fig. 4. Geologic map of basement rocks in the Illinois basin. Basement configuration contours, in thousands of feet, from Bayley and Muehlberger (1968). SGFZ - Ste. Genevieve fault zone.

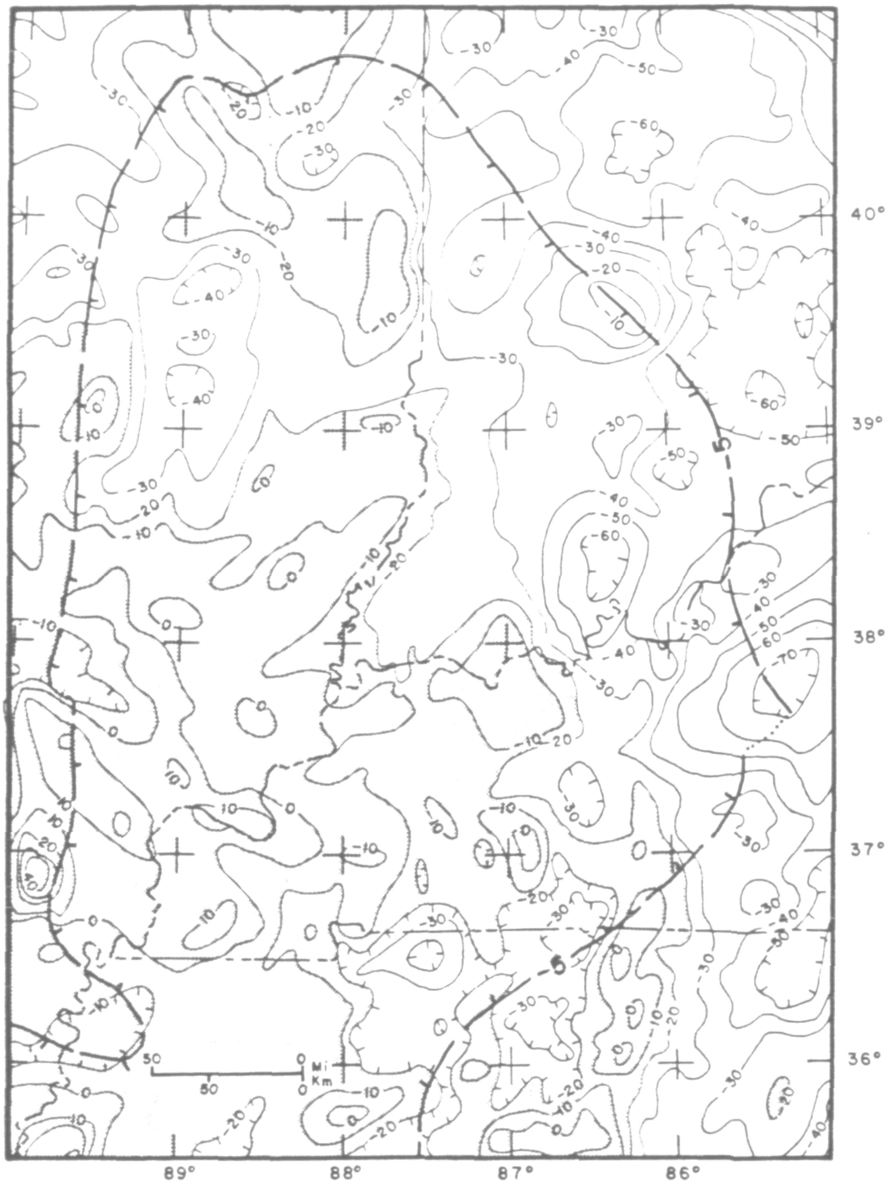

Fig. 5. Bouguer gravity map of the Illinois basin. Contour interval is 10 mgal. From Am. Geophys. Union and U.S. Geol. Survey (1964). Gravity highs - stippled pattern. Dashed hachure line outlining the Illinois basin is the -5,000 ft. contour of Figure 4.

the linear trends more definitively, and outline an important cross trend of local anomalies toward the northeast. The presence of both steep and broad gravity and magnetic gradients suggest that both shallow and deep sources are involved. The most probable causes of the shallower anomalies are a series of associated mafic (and ultramafic?) volcanic and intrusive rocks that have been emplaced along a major northeast-trending rift complex that is discussed in the next section. The presence of basalts in the basement of southern Indiana and western Kentucky (Fig. 4) represent examples of these mafic rocks that occur at the basement surface. The broader anomalies may represent the deeper manifestations of these mafic rocks. The considerable regional extent of the

broad northwest-trending gradient suggests more probably that the anomalies may reflect a major crustal province boundary along which contrasting rock types are juxtaposed.

Pre-Upper Cambrian sedimentary rocks are also present in the Illinois basin (Lidiak and Hinze, 1980; Schwalb and others, 1980). An excellent example occurs in the Texas Pacific No. 1 Farley well, Johnson County, Illinois. The well penetrated 774 feet of white to red quartz sandstone and arkosic sandstone with thin layers of red siltstone beneath the Mt. Simon Formation; crystalline basement was not reached. Lidiak and Hinze (1980) have proposed that the sedimentary rocks are mainly preserved in ancient northeast-trending grabens associated with rift complexes.

Tectonic Interpretation

The Illinois basin is both a depositional and a structural basin. Its present configuration dates from late Paleozoic-early Mesozoic time (Bond and others, 1971; Wilman and others, 1975). Extensive basinal sedimentation began in Cambrian time during development of the Reelfoot basin, which encompassed an area including both the present-day Illinois basin and Mississippi Embayment (Schwalb, 1969). The Illinois basin, open to the south and the site of sedimentation during most of Paleozoic time, was closed by uplift of the Pascola arch, near the end of the Paleozoic era (Bond and others, 1971). The arch connects the Ozark uplift with the Nashville dome. The modern Mississippi Embayment developed as a structural trough in Last Cretaceous and Tertiary time.

Ervin and McGinnis (1975) proposed that the Reelfoot basin is underlain by a Late Precambrian aulacogen (Reelfoot rift) that formed by emplacement of anomalous mantle material and local intrusives into the crust. They regard this structure to be part of a period of widespread rifting that occurred prior to the formation of the Appalachian-Ouachita mountain belt. According to Ervin and McGinnis (1975), the rifting was followed by subsidence in Paleozoic time and by reactivation of the rift in Mesozoic time to form the modern Mississippi Embayment. Hildenbrand and others (1977) have used a linear series of circular positive gravity and magnetic anomalies, which presently delimit the seismic activity in the New Madrid area, to outline this buried rift zone. They regard the rift zone as having been active periodically since the Precambrian. Evidence for the extension of the rift zone northeastward through the deepest part of the Illinois basin has been presented by Braile and others (in press) and is referred to by them as the New Madrid Linear Tectonic Feature. The trend of this structure through the basin is shown on Figure 4. An eastward extension of this rift zone continues into western Kentucky and forms the Rough Creek graben. Soderberg and Keller (1981) regard this graben as a reactivated structure that formed in Late Precambrian-early Paleozoic time.

The most prominent features on the gravity (Fig. 5) and magnetic maps of the Illinois basin are west-northwest-trending anomalies. These anomalies are particularly evident on magnetic maps (Lidiak and Zietz, 1976; Braile and others, in press) where a pronounced magnetic gradient trends through western Kentucky, southern Illinois, and eastern Missouri. The gradient and associated anomalies closely parallel the Ste. Genevieve fault zone (long. 90°W, lat. 38°N) but are much more extensive and can be traced across Missouri and into Tennessee. Preliminary modeling of the anomalies suggests that the causative bodies have a significant depth extent (Braile and others, in press). The gradient thus probably largely reflects a major lithologic province boundary. The Ste. Genevieve fault is regarded as a reactivated fault along an older Precambrian structure.

The Illinois basin is an excellent example of a Phanerozoic intracratonic basin that has developed in part along the site of an older, larger structure, the Reelfoot basin. This correspondence suggests that the Illinois basin is a superposed structure. The older Reelfoot basin represents a preexisting zone of weakness that exercised control on the younger Illinois basin and Mississippi Embayment. Reactivation served to localize the younger structure but did not produce an identical feature, presumably because the stress fields were different. Stresses are obviously generated by a variety of tectonic forces, and forces producing a younger structure may be completely alien to those responsible for an older structure (Hinze and others, 1980).

WILLISTON BASIN

Structural Framework

The Williston basin, which occurs near the junction of the international boundary and the North Dakota-Montana line, occupies western North Dakota and adjacent parts of Montana, South Dakota, Manitoba, and Saskatchewan (Fig. 6). It is both a structural and a sedimentary basin, which dates back to the Cambrian. The present basin was shaped in Late Cretaceous-early Tertiary time by Laramide orogeny. The basin is bounded on the northwest, west, and southwest by a series of domes and anticlines; on the southeast and northeast it merges gradually with the slop-

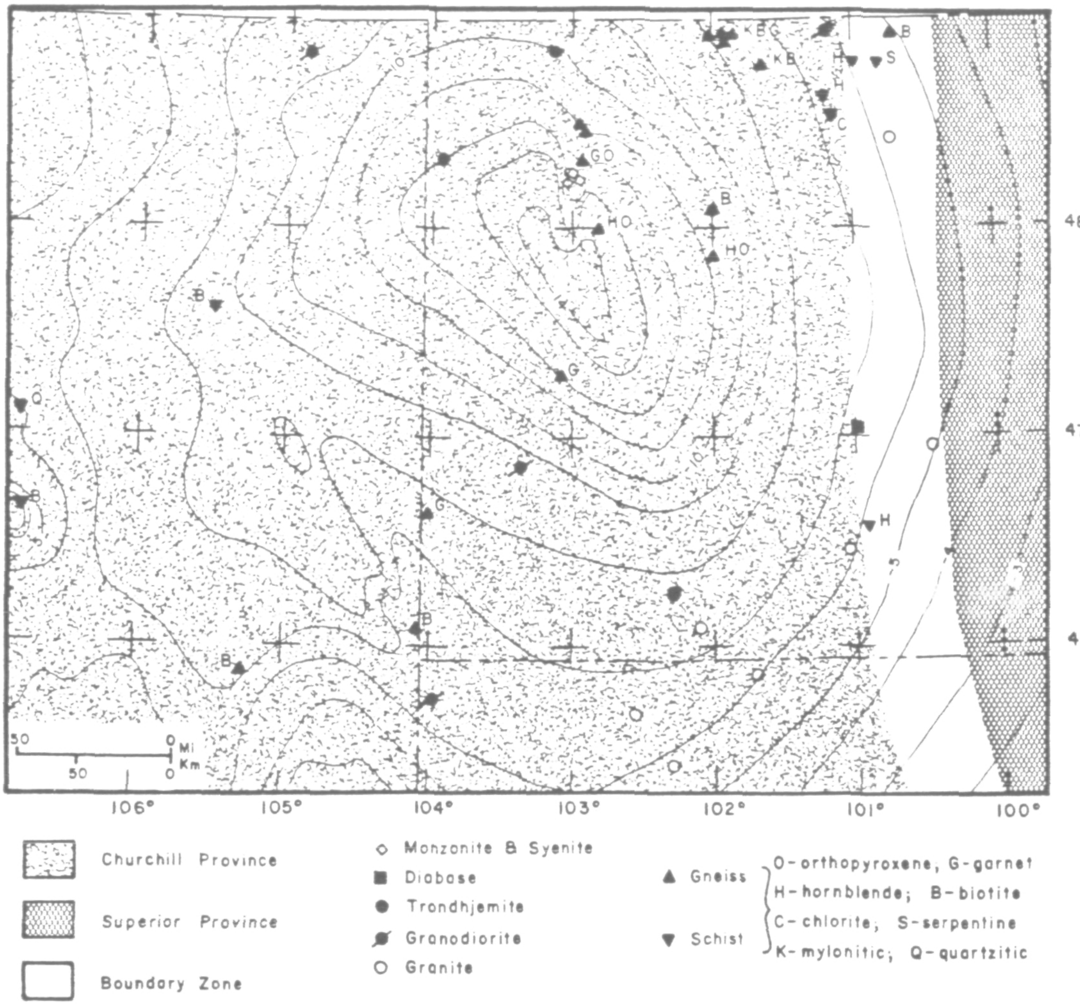

Fig. 6. Geologic map of basement rocks in the Williston basin. Basement configuration contour, in thousands of feet, from Bayley and Muehlberger (1968).

ing Precambrian shelf. Within the basin proper is the north-trending Nesson anticline at long. 103°W, lat. 48°N. The flanks of these anticlines and domes dip gently, on the order of several degrees only. The Precambrian surface is characterized by a relatively gentle slope; maximum depth to basement in the Williston basin is about 16,700 feet (Gerhard, this volume).

The Williston basin had been deformed only during Phanerozoic time. The Precambrian rocks have thus remained a structural entity since the Precambrian, and their present distribution reflects mainly Precambrian structural trends.

Basement Rocks and Regional Geophysics

Approximately 42 wells have been drilled to basement in the general area of the Williston basin (Fig. 6). Most of the wells are located on the shallow eastern flank; only about 12 wells have penetrated the basement in the deeper parts of the basin at depths greater than 10,000 feet. The main rock types are medium- to high-grade sialic metamorphic rocks, granites, and granodiorites. Their distribution is shown on Figure 6.

The combined use of the sparse lithologic data, isotopic age determinations, and regional geophysical maps permits the recognition of two main geological provinces in the area. The boundary between the subsurface extension of the Superior and Churchill provinces trends southward across the eastern flank of the Williston basin (Fig. 6) along an abrupt change in the trend of Bouguer

gravity anomalies. To the east, they trend east-northeast and are associated with greenstones, granites, and high-grade gneisses of Archean age; to the west the anomalies have a general northerly trend and are associated with medium- to high-grade metamorphic rocks, granites, and granodiorites of lower Proterozoic age (Peterman and Hedge, 1964; Goldich and others, 1966; Muehlberger and others, 1967; Lidiak, 1971).

One of the more striking features of the Williston basin is the large gravity high in the interior of the basin. As shown on Figure 7, the anomaly is broad and reaches values as high as about -30 milligals. The anomaly continues in Canada where it bifurcates into two prominent linear highs separated by a low (cf. Am. Geophys. Union and U.S. Geol. Survey, 1964; Observ. Branch, 1964). The eastern of these highs merges with the Nelson River high of Innes (1960). The western anomaly may also join the Nelson high via an arcuate path, but evidence for this trend is less compelling because of a complex anomaly pattern in central Saskatchewan. Wilson and Brisbin (1961, 1962) report that the Nelson River gravity high is underlain mainly by a high-grade gneiss zone and that a gravity low immediately to the northwest coincides with a zone of faulting, amphibolite-grade gneisses, and serpentinized peridotites. Bell (1964; 1966; 1971), Patterson (1963) and others have shown that the rocks in the immediate vicinity of the Nelson River consist mainly of granulites, charnockites, and retrograde gneisses. Bell (1964) further reported that granulites underlie the Nelson River gravity high, in agreement with studies by Gibb (1968 a, b) who found excellent correlation between surface Precambrian rocks, their densities, and the Bouguer anomalies. Gibb demonstrated that the granulites, having an average density of 2.73 ± 0.15 gm/cm^3, can account for the Nelson River gravity high. The main fault zones in the region are regarded by Gibb (1968 b) and Kornik (1969) as being major dislocations that extend deep into the crust.

The boundary between the Churchill and Superior provinces in northern Manitoba has been located at different places in the immediate vicinity of the Nelson River gravity high (Bell, 1966, 1971; Cranstone and Turek, 1976; Weber and Scoates, 1978; Green and others, 1979). Green and others (1979) recognized a broad boundary zone that includes the Nelson River gravity high and adjacent gravity low. They extend the boundary southward beneath the overlying Phanerozoic sedimentary rocks by using a newly-compiled regional magnetic map. This boundary lines up with the Superior-Churchill boundary in the northern United States (Goldich and others, 1966; Muehlberger and others, 1967) and occurs along the east flank of the broad gravity high. The deeper parts of the Williston basin thus lie immediately west of this prominent Precambrian boundary.

Twenty-two wells have been drilled to basement along the broad gravity high (Fig. 7) in western North Dakota. The main rock types are granulite-grade hypersthene gneiss, amphibolite-grade garnet, hornblende, or biotite gneiss, granodiorite, and trondhjemite. The latter two rock types are clearly suggestive of orogenic derivation. These metamorphic and igneous rocks are clearly insufficient to characterize completely the basement under the broad anomaly. The relations are, however, consistent with those reported from the Nelson River zone in Canada and suggest that the gravity high in the Williston is at least partially attributable to granulite and amphibolite facies rocks and igneous rocks of intermediate composition at and near the basement surface. The metamorphic rocks formed deep in the crust and would be expected to have a higher density than rocks metamorphosed at shallower depths. For example, a cylindrical bottom hole core from a granulite in McKenzie County, North Dakota has a measured density of 2.74 gm/cm^3. Similarly, the granodiorites and trondhjemites are typically denser than more granitic rocks.

Monzonites, syenites, and Nesson horst. - Monzonites and syenites also occur in the Williston basin, and their presence poses an interesting problem of distribution and age. The three known occurrences are on the Nesson anticline, which is regarded here as being a horst. The monzonites and syenites are overlain by Upper Cambrian-Lower Ordovician rocks, which contain lithic fragments of these felsic rocks. Feldspathic igneous bodies of this type are typically small and occur mainly as stocks, laccoliths, dikes, and sills. The only other feldspathic rocks in the general region of the Williston basin are in the Little Rocky Mountains of Montana and in the northern part of the Black Hills of South Dakota and Wyoming. These rocks were emplaced and uplifted to their present position along tectonic highs in late Mesozoic-Tertiary times. Peterman and Hedge (1964) dated K feldspar by Rb-Sr methods from one of the monzonites along the Nesson horst and obtained an apparent Late Precambrian age. The basement high, which the monzonites compose, is regarded by them as having been a center of post-Middle Precambrian igneous activity. The monzonites and syenites probably have limited extent in the Williston basin. Their presence along the Nesson horst and in the adjoining

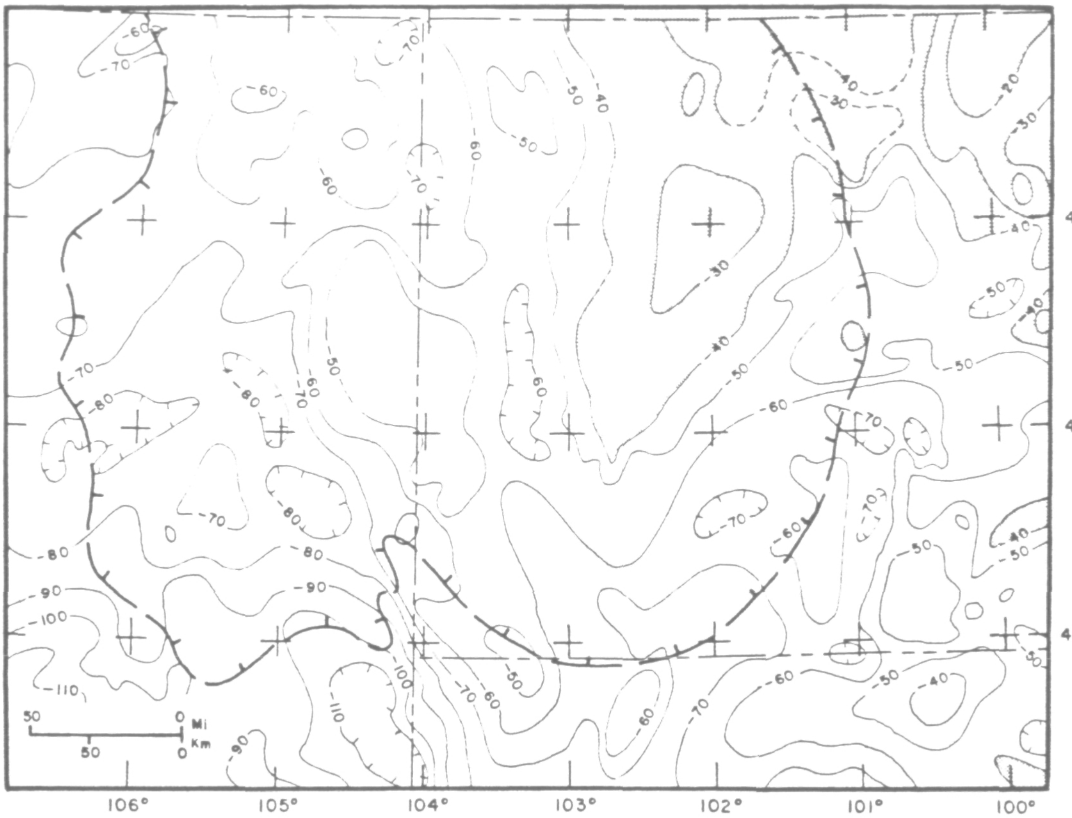

Fig. 7. Bouguer gravity map of the Williston basin. Contour interval is 10 mgal. From Am.Geophys. Union and U.S. Geol. Survey (1964). Gravity highs - stippled pattern. Dashed hachure line outlining the Williston basin is the -7,000 ft. contour of Figure 6.

exposed areas indicates that felsic igneous activity occurred in the region during more than one period of time. The Nesson horst may thus represent an resurgent structure within the Williston basin.

Cryptoexplosion structures. - Probable astroblemes or fossil meteorite craters have been identified within the Williston basin in the subsurface of Saskatchewan, Manitoba, and North Dakota (Sawatzky, 1972, 1975). The structures are circular in outline and contain local intensely deformed strata. Shatter cones have been recognized in cores from McKenzie County, North Dakota (Sawatzky, 1975). Commercial hydrocarbon production occurs along the rims of some of the structures. One of these probable astroblemes in Renville County, North Dakota, has deformed the basement. The basement rocks encountered in several deep holes to the Renville County structure are highly deformed amphibolite-grade garnet and biotite gneisses. Superimposed on the earlier gneissic foliation are irregular, generally sub-horizontal shear planes, cataclastic and mylonitic surfaces, and brecciated zones, all of high complexity. The amphibolite-grade foliation has been largely disrupted. Most of the secondary surfaces are closely spaced. Rounded rock fragments predominate over angular fragments in the brecciated matrix. Definitive meteorite impact features have not yet been recognized in the basement rocks. These local structures probably have no direct relation to the tectonic development of the basin.

Tectonic Interpretation

The presence of granulite-grade and amphibolite-grade gneisses and igneous rocks of intermediate composition near the basement surface has an important implication for the tectonic development of the Williston basin, which is commonly regarded as dating back to the Cambrian at which time subsidence began. Its history, however, is more complex. The basin probably owes its early development to processes operating in Precambrian

time. An explanation of the gravity highs and the high-grade gneisses in the Williston basin seemingly requires major crustal uplift and accompanying erosion in the area now underlain by the gravity feature. The time to uplift cannot be stated precisely; it probably began after the widespread 1800 m.y.-old metamorphism, and may have continued into Late Precambrian or Early Cambrian time. Fault zones containing dense crustal rocks, such as the granulites, were brought to the basement surface. A gravity high could be produced by the juxtaposition of deep and shallow crustal rocks. The possibility of portions of the Williston basin being underlain by a complex orogenic boundary similar to that occurring along the Nelson River area in Canada will require further more detailed studies.

SALINA AND FOREST CITY BASINS

Structural Framework

The Salina and Forest City basins are structural and depositional basins. Both are shallow basins, having a depth to basement of about 4000 feet. Configuration of the basement surface is shown on Figure 8. The two basins are separated by the prominent north-trending Nemaha uplift, a Late Mississippian (pre-Desmoinesian)-Early Pennsylvanian structure (Merriam, 1963; Adler and others, 1971). Prior to that time, a single basin, the North Kansas (or Iowa) basin was present.

The Salina basin is limited on the north by the Siouxana arch, on the east and southeast by the Nemaha ridge, on the west by the Cambridge arch, and on the southwest by the Central Kansas uplift. Secondary structures within the basin are outlined by Cole (1962) and Carlson (1967). The geologic history of the Kansas portion of the basin is summarized by Lee (1956). The Nebraska part is summarized by Reed (1954) and Carlson (1963).

Structural features that outline the Forest City basin are the Thurman-Redfield fault to the north, the Mississippi River arch to the east, the Nemaha ridge to the west, and the Bourbon arch to the south. Within the basin are two opposing structural trends, an older northwest trend and a younger northeast trend. Anderson and Wells (1968) discuss the geologic history of the basin.

Basement Rocks and Regional Geophysics

Numerous wells to basement have been drilled along the arches and ridges that encircle the two basins. The basement geology in these contiguous areas are described elsewhere (Muehlberger and others, 1967; Lidiak, 1972; Kisvarsanyi, 1974; Denison and others, in press; Bickford and others, 1981). In contrast to the uplifts, only a few wells to basement have been drilled in the basins proper. As in the other basins, interpretation of the basement geology thus requires not only study of the available wells to basement but also an evaluation of the regional geophysical anomalies.

The wells to basement in the Salina and Forest City basins are shown in Figure 8. The available data suggest that the main rock types in the northern part of the Salina basin are gneissoid rocks of granite and granodiorite composition, nonfoliated anorogenic granite and granodiorite, and minor silicic metamorphic rocks (Denison and others, in press). The southern part of the basin is underlain by Keweenawan basalts and associated immature sedimentary rocks. There are no wells to basement near the center of the basin.

The type of basement rocks in the Forest City basin is also poorly known. Gneissoid granitic rocks have been encountered along the western flank and near the center of the basin. Keweenawan basalts and associated sedimentary rocks occur in a northeast-trending belt in the northern part of the basin. The lithology of the basement in the remainder of the basin is unknown because of the complete lack of well control.

Gravity anomalies suggest that additional mafic rocks may be present within the basement of both basins. Figure 9 is a Bouguer gravity map of the two-basin area. The pronounced northeast-trending gravity high and flanking low are part of the well-known Midcontinent gravity anomaly. These anomalies coincide with a major continental rift zone in which a thick sequence of Keweenawan basaltic and associated sedimentary rocks accumulated (King and Zietz, 1971; Lidiak, 1972; Ocola and Meyer, 1973). Other gravity highs are also present within both basins. In the east-central part of the Salina basin at longitude 98°W along the Kansas-Nebraska state line is a broad gravity high. Two other broad highs occur to the south-southwest, forming an apparent trend that parallels the Midcontinent gravity anomaly in Kansas. In the Forest City basin at lat. 40°N, long. 95°W is a small gravity high that occurs immediately south of the deepest part of the basin. The low amplitude and broad gradients associated with these basinal anomalies suggest that the source is buried at depth within the intrabasement. Their proximity and the parallelism of the anomalies in the Salina basin to the Midcontinent gravity anomaly suggest a relationship. The anomalies possibly reflect the intrusion of gabbroic igneous rock at moderate depth within the sialic crust. Steeples (this volume) shows that an anomalous mantle occurs along a broad zone beneath both the Salina and Forest City basins and is centered on the Midcontinent gravity anomaly.

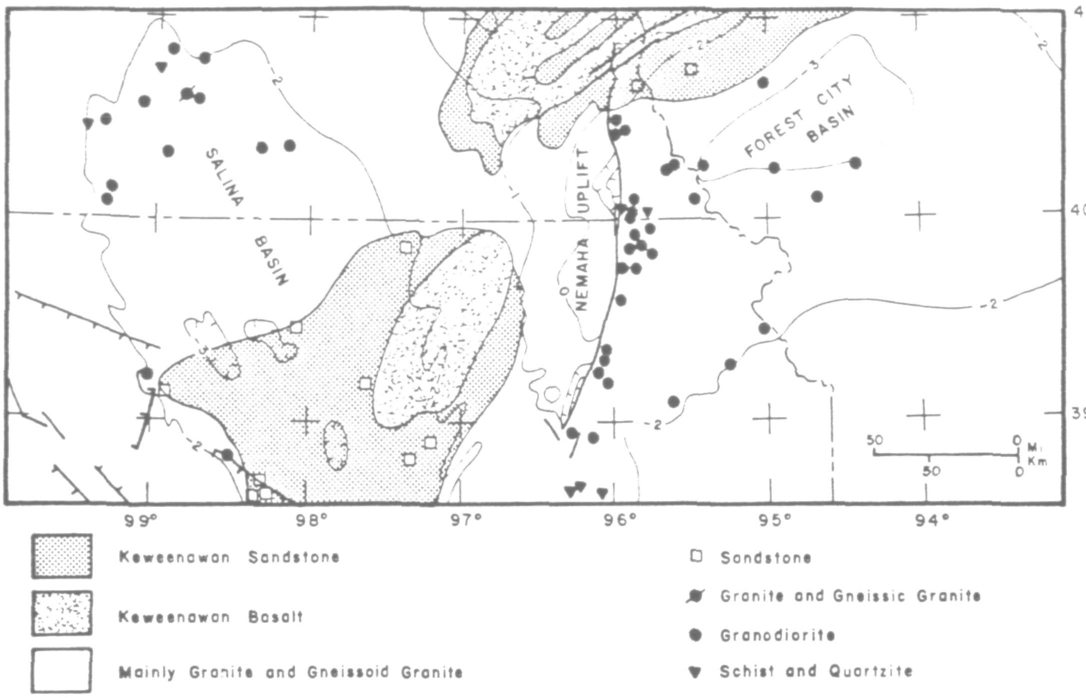

Fig. 8. *Geologic map of* basement rocks in the Salina and Forest City basins. Basement configuration contours, in thousands of feet, from Bayley and Muehlberger (1968).

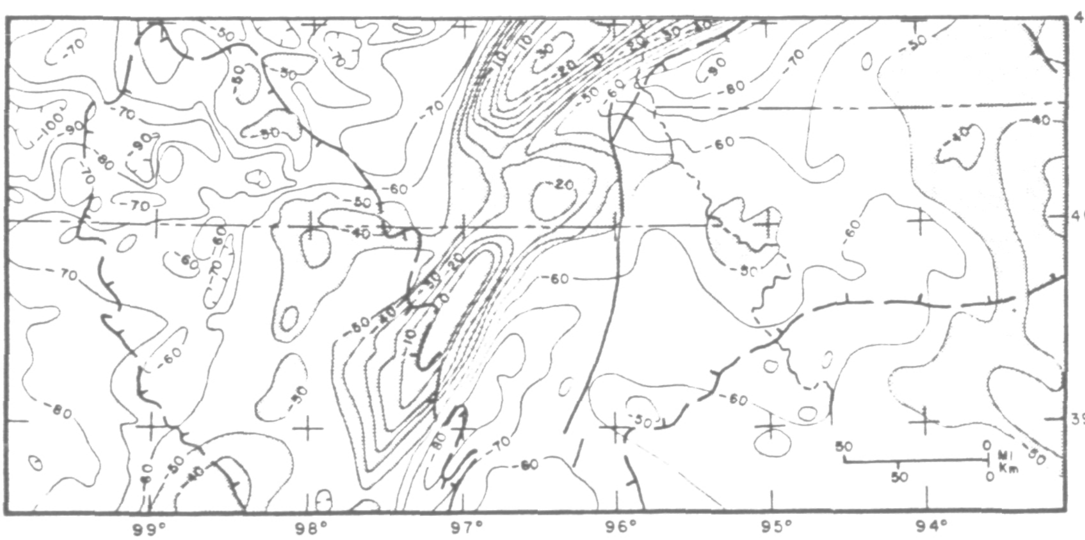

Fig. 9. Bouguer gravity map of the Salina and Forest City basins. Contour interval is 10 mgals. From Am. Geophys. Union and U.S. Geol. Survey (1964). Gravity highs - stippled pattern. Dashed hachure line for each basin is the -2,000 ft. contour of Figure 8.

ARKOMA BASIN

Structural Framework

The Arkoma basin is an elongate east-northeast-trending structural and depositional basin that is bounded on the north by the Ozark uplift and on the south by the Ouachita Mountain system (Fig. 10). The basin, once part of the larger Ouachita geosyncline, formed in late Paleozoic time during the Ouachita orogeny and contains over 30,000 feet of pre-Missourian Pennsylvanian strata (Flawn and others, 1961; Branan, 1968).

Two main structural patterns occur in the basin. To the south are numerous east-trending anticlines, synclines, and northward-thrust faults. The folds and faults occur with increasing intensity toward the Ouachita front. Maximum sedimentary thickness and the deepest part of the basin is adjacent to the Ouachita front in the region of greatest thrusting and folding. This structural style gives way toward the north to high-angle block faulting. These faults probably formed during basinal subsidence.

Basement Rocks and Regional Geophysics

Three wells have been drilled to basement in the Arkoma basin. All are located along the steep northern slope (Fig. 10). Two of the wells bottomed in metarhyolite porphyry and the other encountered a medium-grained two-feldspar hornblende granite (Denison, 1966, in press). Rb-Sr ages of 1270 m.y. on the metarhyolite and 1240 m.y. on feldspar from the granite indicate that the granite is younger than the rhyolite and may have metamorphosed it (Muehlberger and other, 1966; Denison, 1966, in press).

Figure 11 is a Bouguer gravity map of the Arkoma basin. A prominent -100 milligal gravity low strikes east-northeast through the center of the basin. The close similarity between the basement configuration (Fig. 10) and the gravity anomaly contours is due to the fact that the form and depth of the deep basin is based on the gravity data (Bayley and Muehlberger, 1968).

The most significant feature of Figure 11 is the -100 milligal gravity low that occurs in the area of

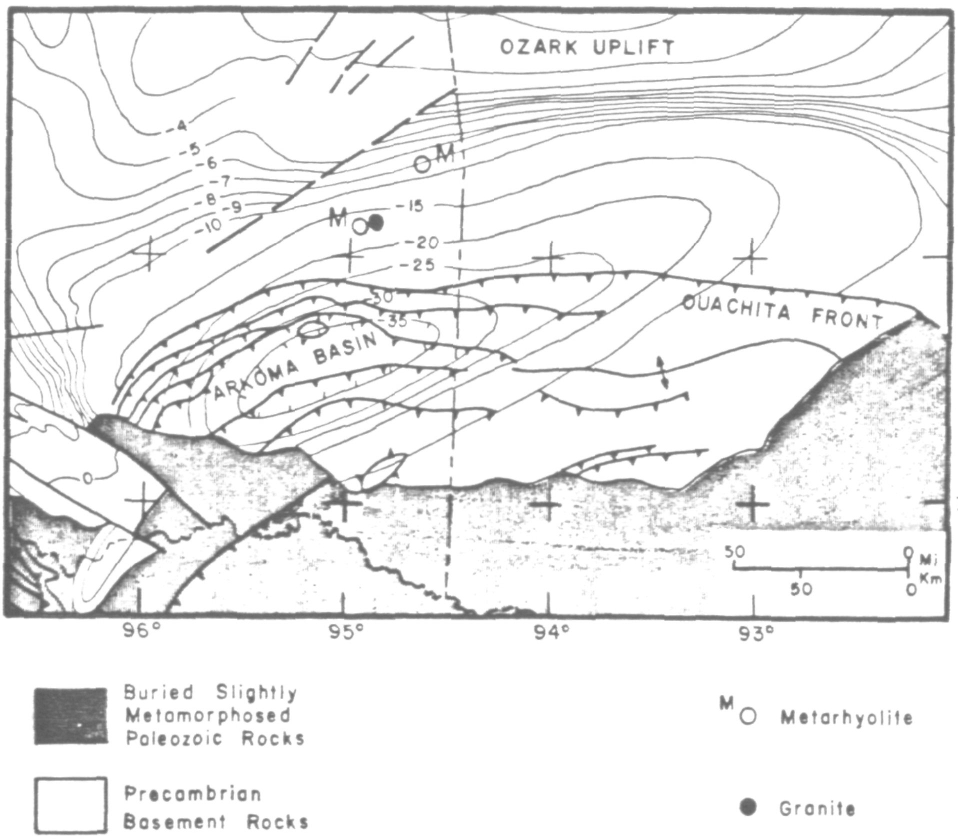

Fig. 10. Basement configuration map of the Arkoma basin. Contours, in thousands of feet, are from Bayley and Muehlberger (1968).

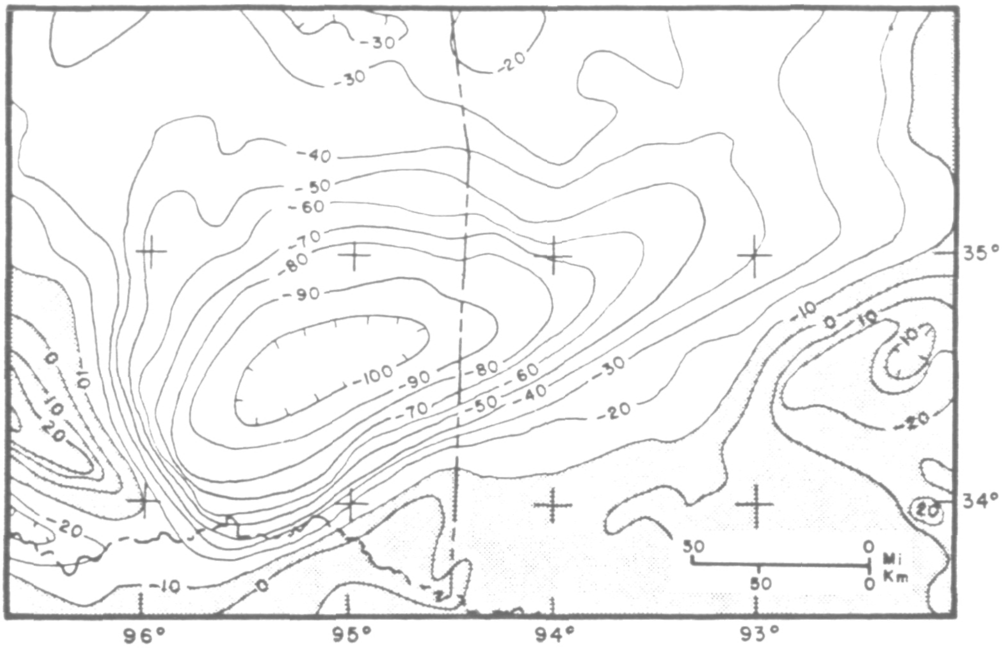

Fig. 11. Bouguer gravity map of the Arkoma basin. Contour interval is 10 mgal. From Am. Geophys. Union and U.S. Geol. Survey (1964).

the Arkoma basin. The basin thus differs from those previously described in this report in the absence of a gravity high and in the large magnitude of the gravity low. The gravity anomalies suggest that the basin is filled with a thick section of low-density sedimentary rocks. The absence of a gravity high implies that the basement consists of low or moderate density material. Consistent with this interpretation is the presence of rhyolite and granite along the north flank of the basin. Rocks of this type are probably widespread in the basement beneath the Arkoma basin. If denser basement rocks are present, they are evidently masked by the thick sedimentary sequence.

DISCUSSION

Types of Midcontinent Basins

The origin and development of basins in continental areas have long been controversial topics. Basins typically contain a thick accumulation of sedimentary rocks that accumulated over a long time span. Igneous rocks are sparse or absent; where present they occur as minor intrusions, dikes, sills, laccoliths, or as thin ash layers and were generally emplaced in the later stages of basin development. The rocks filling the basins are unmetamorphosed except the deepest parts where incipient effects may be present. Structures within basins are generally subtle and consist of minor folds and normal or strike-slip faults. In basins adjacent to orogenic belts, more complex folds, thrust faults, and listric faults may occur. The early history of most basins is imperfectly known because of deep burial.

Recently, several models have been proposed to account for the origin of major continental basins. These models involve essentially a prolonged one-stage process that includes the generation of a thermal anomaly followed by thermal contraction (Sleep, 1971; Sleep and Snell, 1976; Haxby and others, 1976) or extensional tectonism accompanied by a thermal anomaly (McKenzie, 1978; Jarvis and McKenzie, 1980). These theories account for many aspects of basin development but do not appear to be consistent with the general absence of thermal effects within most basins.

A second prominent problem involves the fact that not all basins have had the same origin. On regional geologic considerations alone, basins that form in foreland areas marginal to orogenic belts such as the Appalachian basin and the Arkoma basin are distinguishable from basins, such as the Michigan basin, that occur in intracratonic areas (Umbgrove, 1947; Kay, 1951; King, 1959). Foreland basins are closely associated with orogenic belts and are apparently compatible with an origin by a one-stage process. Characteristic features are the development of a deep downwarped basin parallel to the mountain front, orogenic sedimentary pat-

terns, and orogenic structural styles Basin development and deposition are in part synchronous with compressional folding in the adjacent orogenic belt (Cooper, 1968 Rodgers, 1970 Cloos 1971) In contrast to these basins are intracratonic basins which are removed from orogenic belts and occur in areas of subsidence These basins are mainly nonlinear in outline, contain mostly mature sedimentary rocks, and are essentially undeformed except for minor block faulting A third type of basin that is now widely recognized is an aulacogen These are long troughs extending into continental cratons from fold belts (Burke and Dewey, 1973 Hoffman and others, 1974, Burke, 1977) Their properties include a long history as an active structure, a thick, gently folded sedimentary sequence, the emplacement of igneous rocks generally in the early stages of development, a complex of horsts and grabens within the aulacogen, and the occurrence of reactivated structures

A compilation of basins of the Midcontinent and areas marginal to the craton reveals that all three types of basins are present The basins are shown according to type in Table 1

Table 1 Basins of the Midcontinent and Adjacent Areas, United States

A	Intracratonic Basins
	Michigan Basin
	Williston Basin
	Illinois Basin
	Salina-Forest City Basins
B	Foreland Basins
	Arkoma Basin
	Appalachian Basin
	Denver Basin
	Black Warrior Basin
C	Aulacogens
	Southern Oklahoma
	Mississipi Embayment
	Delaware Basin

As discussed previously, intracratonic basins are underlain by distinct geophysical anomalies, either Bouguer gravity highs, magnetic highs, or both Most of the anomalies are linear They reflect old, mainly Precambrian structures, along which dense and (or) magnetic rock has been juxtaposed against more typical sialic material The geophysical signatures and available basement geological data of each basin indicate that the anomalies are attributable either to old basaltic rift zones in the basement complex, or to major Precambrian tectonic boundaries Muehlberger and others (1967) first recognized that a large proportion of dense (mainly mafic) rock underlies these basins, and McGinnis (1970) proposed that the basins are sites of collapsed one-stage rift systems

In contrast to intracratonic basins, foreland basins do not appear to be associated with gravity or magnetic highs These basins are underlain instead by gravity lows which, in part, reflect a thick accumulation of sedimentary material A possible exception is the Black Warrior basin which contains a prominent gravity high in the northern part However, the Black Warrior is a complex basin, occurring in a recess between the converging Appalachian and Ouachita fold belts It is divisible into a southern structural province of thrust faults and a northern province of normal faults (Flawn and others, 1961, Thomas, 1972)

The three aulacogens listed in Table 1 have geophysical signatures that are more similar to intracratonic basins than foreland basins and are probably underlain in part by dense mafic rock The southern Oklahoma aulacogen (Hoffman and others, 1974), which includes the Anadarko, Ardmore, and Marietta basins and flanking Wichita and Amarillo uplifts (Ham and others, 1964) contains linear gravity and magnetic highs and lows Brewer and others (in press) present evidence for the existence of an earlier extensive Proterozoic basin in this area They suggest that the aulacogen may have had a much longer history of subsidence or that it may represent a younger reactivated structure The second-listed aulacogen, the Mississippi Embayment, also contains gravity and magnetic highs that form linear trends (Ervin and McGinnis, 1975, Hildenbrand and others, 1977) These workers suggest that the aulacogen formed in late Precambrian time and was reactivated during the late Mesozoic Similarly, recent work by Keller and others (1980) has shown that the Delaware basin occurs adjacent to a gravity high and is also a probable aulacogen that had an origin similar to the southern Oklahoma aulacogen

Origin of Intracratonic Basins

The presence of older structures in the basement underlying intracratonic basins is noteworthy and suggests that the sites where intracratonic basins developed have had complex histories One-stage models have the inherent difficulty of not accounting for the lack of symmetry between the older structures and the overlying basin and the long time span of development For example, the thermal contraction model proposed by Haxby and others (1976) attempts to relate the underlying 1100-m y -old linear Keweenawan rift with the formation of the circular Michigan basin, which began to subside in early Paleozoic time As

noted by Brewer and Oliver (1980), a direct relation is difficult to visualize

A more complex sequence of events seems necessary to explain the development of these basins Intracratonic basins apparently occur along sites of older structures The first step appears to be the formation of a major fault zone or other tectonic boundary These structures would presumably be of sufficient magnitude to modify the crust for tens of kilometers both horizontally and at depth Possible structures would include rift zones, large strike-slip or transform fault zones, lithologic, tectonic, or metamorphic province boundaries, and local basement inhomogeneities in the form of mafic or ultramafic intrusions (Hinze and others, 1980)

The second stage would involve the development of the basin itself and would occur at some later but unspecified time Subsidence is initiated in response to (new) tensional forces The new strain field would be unrelated to earlier regimes and would produce a different type of structure However, the tensional forces would be localized along the older structures, which represent old zones of weakness in the crust Basins would thus tend to form along older reactivated structures

It perhaps needs to be emphasized that a reactivated structure does not necessarily produce a basin Extensional tectonism operating over a long period of time is apparently necessary, and reactivated structures are clearly not all extensional A variety of reactivated structures are present in the Midcontinent, and models to explain their development are discussed by Hinze and others (1980)

The formation of intracratonic basins by reactivation of older structures during periods of extension is an example of intraplate tectonism Development of these basins contrasts with tectonic processes operating along plate boundaries The basins contain the accumulated products of long-term dynamic systems and encompass a considerable geologic record Their formation along old zones of weakness by reactivation of earlier structures indicates that they have had a more complex history than generally envisaged They are thus important in understanding the structure, behavior, and evolution of continents A consideration of basin development must take into account the Precambrian as well as the overlying Phanerozoic rocks

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Appendix 10. Preprint of Paper to be Published as U. S. Geological Professional Paper 1241-C, 1984.

GEOLOGY AND GEOCHRONOLOGY OF PRECAMBRIAN ROCKS IN THE CENTRAL INTERIOR REGION OF THE UNITED STATES

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ABSTRACT

Rocks of the buried Precambrian crust in the Central Interior Region range from more than 2.7 to less than 1.0 b.y. in age and from granite and granulitic gneiss to gabbro and basalt in rock type. The oldest rocks occur in the Dakotas and are clearly buried portions of the Canadian Shield; they are mostly greater than 2.5 b.y. old and some may be as old as 3.6 b.y. The central part of this region, including Nebraska, northern Missouri, and northern Kansas, is underlain by diverse igneous and metamorphic rocks whose ages are mostly 1.6 to 1.8 b.y.; scattered anorogenic granitic plutons whose ages are about 1.4-1.5 b.y. are also known in this terrane.

The most distinctive feature of the continental interior is the great terrane of felsic igneous rocks that makes up the basement from Ohio and Wisconsin across southern Missouri and Kansas and into Panhandle and far western Texas. These rocks, which include abundant rhyolite and mesozonal and epizonal granitic bodies, range in age from 1.5-1.2 b.y., with a general tendency for ages to decrease from northeast to southwest; older rocks are not known anywhere within this terrane. Toward the east in Ohio, eastern Kentucky, and eastern Tennessee, and toward the south in central Texas, the basement terrane consists of medium grade metamorphic rocks and associated granitic plutons that formed mainly 1.0 to 1.1 b.y. ago.

A belt of basalt, interflow arkosic sandstone and siltstone, and related mafic intrusive rocks can be traced with the aid of geophysical data from the Lake Superior region southward into central Kansas. This feature, the Central North Ameircan Rift System, is widely believed to be an abortive continental rift that formed about 1.1 b.y. ago. Geophysical data suggest that other areas in the eastern part of the interior are also underlain by rift basalts and related rocks.

The Central Interior Region was dominated by eugeosynclinal sedimentation and orogenic tectonics prior to about 1.6 b.y. ago. After that time the region apparently stabilized, and the sedimentation was characterized by the deposition of sheets of quartzose sandstone about 1.6 b.y. ago. Subsequent igneous activity, sedimentation, and tectonics have been dominantly anorogenic except along the margins of the stable interior.

INTRODUCTION

Our understanding of the Precambrian in the Central Interior Region is based upon widely separated outcrop areas and samples from irregularly distributed, but numerous, wells drilled largely in search of oil and gas. Flawn (1956) showed that it was possible to make a map of the buried Precambrian based on drill-hole samples, and the larger-scale study of

Muehlberger et al. (1967) led to publication of the Basement Rock Map of the United States (Bayley and Muehlberger, 1968). These works remain the foundation of our present knowledge. The geology and geochronology of the scattered surface exposures are now much better known, but the geochronology of the subsurface has received little attention, and the basic reference work is the series of papers by Goldich and his co-workers (1966).

The rocks in the Central Interior Region are here divided into four general types: (1) deep-seated granitic and metamorphic rocks similar to those exposed in the shield areas; (2) anorogenic mesozonal and epizonal granite; (3) rhyolite and epizonal granite; and (4) basalt and gabbro of "rift" type.

The first type is typical of rocks exposed in the Precambrian shields. These are diverse and strongly deformed rocks together with undeformed massive plutons that are characteristically older than about 1,600 m.y. The marked density and magnetic contrasts of these rocks allow extrapolation by geophysical methods in areas where drill control is lacking. About 18 percent of the Central Interior Region is underlain by rocks of this type.

The second type is characterized by anorogenic mesozonal to epizonal granitic plutons, formed 1,300 to 1,500 m.y. ago, and associated with relatively minor metasedimentary and metaigneous rocks. Silver et al. (1977) and Emslie (1978) have discussed the importance of these rocks, which form a discontinuous band from northeastern New Mexico to central Missouri and probably eastward to the Grenville Front in the Central Interior Region. We estimate that 13 percent of the continental interior is underlain by these rocks.

The third type is characterized by large tracts of rhyolite and associated epizonal granite. These were first recognized in the subsurface by Muehlberger et al. (1966, 1967), and additional drilling has shown that much of the area east of the Mississippi River and west of the southward extension of the Grenville Province is also underlain by similar rocks. Although the origin of the epizonal granite-rhyolite terrane remains unclear, certain conclusions may be drawn from our present understanding:

(1) The rocks are preserved in structural depressions; surrounding rocks represent deeper crustal levels of emplacement.

(2) The rhyolites are invariably associated with coeval hypersolvus granites that commonly display micrographic quartz-perthite intergrowths.

(3) The rhyolites are not associated with any significant volume of other volcanic or sedimentary rocks.

(4) The rhyolites are essentially undeformed and only locally recyrstallized.

(5) The several tracts of rhyolite-granite are similar but not the same in age; the ages show no simple pattern of variation.

The rhyolite-epizonal granite association underlies an estimated 52 percent of the continental interior, although much of this area is east of the Mississippi River where drill-hole control is poor. The abundance of these rocks is the major difference between the buried Precambrian of the continental interior and the exposed shield areas. Gravity and magnetic observations are of limited value in extrapolating these rocks into areas where drill control is poor.

The extension of Keweenawan basaltic and gabbroic rocks from the Lake Superior Region into the Central Interior Region along the Central North American Rift System has yielded the fourth major rock association. Basaltic rocks and related arkose can be traced as far as east-central Kansas on the basis of scattered well samples and gravity and magnetic data. That smaller areas east of the Mississippi River are also underlain by similar mafic igneous rocks can be inferred from geophysical measurements. These rocks are possibly time correlative with the Keweenawan associations. We estimate that about 10 percent of the interior is underlain by rocks of this type.

Perhaps the single most significant feature of the Precambrian rocks of the Central Interior Region is the great preponderance of granite and related volcanic rocks. These rocks, which generally have petrographic features indicating that they were emplaced at shallow to intermediate crustal levels, make up about two-thirds of the continental interior. Mafic rocks occur mostly along the central North American Rift System. Igneous rocks of intermediate composition are exceptionally rare. The greenstone belts which so characterize the older shield areas are confined to the buried extensions of the shield in Area 1, and thus make up only about 1 percent of the Central Interior Region.

Sedimentary rocks are also notably rare. Shelf-type sedimentation evidently began about 1,700 m.y. ago, but the major deposits were of clean sandstone. Carbonate rocks are virtually unknown, and all the sedimentary rocks make up only an estimated 7 percent of this great region.

Area I. North and South Dakota

The characterization of the buried basement complex in North and South Dakota is based on gravity and magnetic anomalies and on lithologic study of several hundred basement well samples (Muehlberger et al., 1967). These data indicate that the eastern Dakotas are mainly part of the subsurface extension of Archean rocks of the Canadian Shield. The western Dakotas are a continuation of mainly Proterozoic rocks of the Canadian Shield.

Archean Time

Gneiss: Gneiss of Archean age is apparently widespread in eastern North and South Dakota. The oldest rocks (Fig. 2) are granitic and granulitic gneisses that crop out in the Minnesota River Valley (Goldich et al., 1961, 1970) and extend along a series of prominent gravity and magnetic anomalies from near Duluth, Minnesota, west-southwestward to east-central South Dakota (Lidiak, 1971; Morey and Sims, 1976). Detailed radiometric studies of the Minnesota River Valley rocks (Goldich et al., 1970; Goldich and Hedge, 1974) have shown that they are at least 3,5000 m.y. old and that one phase appears

to be 3,700 m.y. old. Metamorphism and granite emplacement about 2,700 m.y. ago and a thermal event about 1,800 m.y. ago have partly obliterated the earlier geologic history of the gneisses.

Granitic gneiss is shown on Figure 2 as the predominant rock type in five other areas of northeastern South Dakota and in a large area of northeastern North Dakota. The belts in South Dakota are associated with west-southwest-trending gravity lows and magnetic highs; five wells to basement encountered granitic and gneissic rocks. In North Dakota the gravity anomalies are less distinct, but 22 wells to basement demonstrate the granitic and gneissic character of the terrane. Mineral assemblages in the gneisses indicate widespread metamorphism to the amphibolite facies.

Sparse radiometric data indicate that the gneisses are of probable Archean age (Burwash et al., 1962). A further indication of age is the continuation of geophysical anomalies associated with Archean gneisses of the Canadian Shield into the eastern Dakotas. The higher grade of metamorphism in the gneisses compared to Archean greenstones suggests that at least some of the gneisses predate the 2.7 b.y. old Algoman orogeny.

Rocks of Archean age are also present in the Black Hills (Zartman and Stern, 1967; Rateé and Zartman, 1970; Kleinkopf and Redden, 1975). Two granulites from near the center of the Williston Basin may also be Archean in age because they occur along a prominent linear gravity high which can be traced northward to the Nelson River high of Innes (1960). The Nelson River high has been correlated with Archean granulitic gneisses that were involved in both the Kenoran and Hudsonian orogenies (Patterson, 1963; Bell, 1966; Gibb, 1968; Kornik, 1969).

Greenstone: Belts of greenstone and related rocks are extensive in the basement of the eastern Dakotas. Seven belts, characterized by gravity highs and less pronounced but linear magnetic highs, are shown on Figure 2. Study of 18 samples indicates that amphibole schists and gneisses are dominant; serpentinite is present in one basement well. Modal compositions suggest mafic and ultramafic igneous antecedents. A staurolite schist in northeastern South Dakota indicates that metasedimentary rocks are associated with the greenstones. The rocks are characterized by metamorphism to the greenschist or lower amphibolite facies.

No age determinations have been published for any of the supracrustal rocks in the Dakotas. They are regarded as being of Archean age because the assoicated gravity and magnetic anomalies continue into northern Minnesota where they coincide with greenstone and iron-formation of the Keewatin Group, which was dated at about 2,700 m.y. (Hart and Davis, 1969).

Granite and granodiorite: Coarse-grained, two-feldspar granite (21 wells) is interpreted as the principal rock type in large areas of the eastern Dakotas (Fig. 2). Granodiorite and trondhjemite (7 wells) and amphibolite-grade gneiss (7 wells) are also present but are apparently subordinate to granite. These rocks lie in the subsurface extension of the Superior province of Canada and are characterized by gravity and magnetic lows. The granite and related rocks in the eastern part of Figure 1 have the same general trend as the greenstones and are interpreted as being part of an Archean greenstone-

granite terrane that was involved in the Algoman orogeny. K-Ar and Rb-Sr ages on minerals from both granite and gneiss reflect mainly the widespread igneous activity and metamorphism that occurred during this orogeny (Burwash et al., 1962; Peterman and Hedge, 1964; Goldich et al., 1966).

Proterozoic time (Interval Occurring 1,600-2,500 m.y. ago)

Metamorphic rocks: The east-northeast-trending anomalies of the Superior province are terminated in the central Dakotas by northwest-trending anomalies of the Churchill province (Muehlberger et al., 1967; Lidiak, 1971). The alignment of gravity and magnetic anomalies implies a northwest structural trend of the basement rocks. Three metamorphic belts are inferred. The belt in the central Dakotas is marked by magnetic highs and both highs and lows in gravity. The few wells to basement suggest that the area is underlain by mafic and silicic schist and gneiss. The belt in south-central South Dakota continues into Nebraska and coincides with magnetic and gravity lows. The rocks are dominantly silicic schists (Lidiak, 1972). The third metamorphic belt trends through the Black Hills and continues into Montana. This belt also coincides with a magnetic low. The rocks are mainly medium-grade metasedimentary rocks, locally intruded by granite. Gough and Camfield (1972) suggest that graphitic schist may be abundant.

The presence of Archean granitoid rocks in the Black Hills suggests that these metamorphic belts probably developed on a sialic crust within a craton rather than along a continental margin. The time of deposition is inferred to have been about 1,900-2,100 m.y. ago.

Goldich et al. (1966) concluded that the rocks in the western Dakotas were involved in orogeny 1,700-1,900 m.y. ago. Most of the ages are of minerals from metamorphic rocks. The basement may include older rocks whose ages were reset by younger metamorphism as well as rocks formed at that time. The metamorphic belts possibly date from earlier Proterozoic time, but this dating can be demonstrated only in the Black Hills, where Archean granite gneiss (Zartman and Stern, 1967) is unconformably overlain by a thick metasedimentary succession which was folded, metamorphosed, and intruded by granite 1,700-1,900 m.y. ago during the Black Hills orogeny (Goldich et al., 1966).

Granites: Granite (11 wells) occurs at scattered localities in the western Dakotas. Apparent radiometric ages on minerals and whole rock samples are in the range 1,660-1,810 m.y. (Goldich et al., 1966). The granites probably formed during the major period of orogeny in the western Dakotas.

Silicic volcanic rocks: Silicic volcanic rocks are present in eastern South Dakota. These rocks are essentially unmetamorphosed and apparently overlie the older plutonic complex. Three determinations yield ages of 1,680-1,700 m.y. (Goldich et al., 1966). Petrographically similar rhyolitic volcanic rocks occur in adjacent northwestern Iowa (included in undifferentiated felsic rocks on Figure 3).

Proterozoic time (Interval Occurring 900-1,600 m.y. ago)

Granite: Four Rb-Sr whole rock or feldspar ages on granite from southern South Dakota and adjacent Nebraska are in the range 1,480-1,510 m.y. (Goldich et al., 1966). These rocks are probably related to the anorogenic granites discussed in Part II.

Mafic and Ultramafic Rocks: Diabase, diorite, gabbro, and pyroxenite occur in scattered wells in North and South Dakota. Except for deuteric alteration in the diabases, the rocks are unaltered and thus intrusive into the plutonic complex. Their age is unknown, but they probably reflect several intrusive episodes. They are tentatively regarded as post-dating regional metamorphism and thus being less than 1,750 m.y. old.

Sioux Quartzite: The Sioux Quartzite is a uniform, mildly folded, subhorizontal formation that is nonconformable on the underlying plutonic complex. It is extensively developed in the surface and subsurface of southeastern South Dakota and extends into adjacent Minnesota, Iowa, and Nebraska. The formation is composed mainly of silicified quartz sandstone that is conglomeratic near the base, and minor thin beds of red shale and argillite. The presence in the essentially undeformed quartzite of diaspore plus quartz and pyrophyllite plus quartz (Berg, 1938) suggests hydrothermal or burial metamorphism under static conditions.

Pebbles of iron formation in the Sioux Quartzite indicate that the unit may be no older than about 1.9 b.y. (Goldich, 1973), and a Rb-Sr age determination on a rhyolite from Sioux County, Iowa, suggests that it may be at least 1,520 m.y. old (Lidiak, 1971). A nearby well is reported to have penetrated alternating layers of rhyolite and quartz sandstone (Beyer, 1893). Similar silicic volcanic rocks in South Dakota yield ages of 1,680-1,700 m.y.; the Baraboo Quartzite of Wisconsin, often considered to be correlative with the Sioux Quartzite, rests upon rhyolite whose U-Pb zircon age is 1,760± 10 m.y. (Van Schmus, 1978).

Area II: Nebraska, Iowa, Northern Missouri, Northern Kansas, and Eastern Colorado

Basement rocks in Area II include a variety of igneous, metamorphic, and sedimentary rocks whose ages range from at least 1,800 m.y. to about 1,000 m.y. The distribution and petrography of these rocks has been learned primarily from study of cuttings and cores from deep drilling, but geophysical data have also been used to extend terranes mapped on the basis of well samples. Large numbers of well samples are available in Nebraska and Kansas because of oil and gas exploration; these have been studied by Lidiak (1972) in Nebraska and by Scott (1966) and Bickford et al. (1979) in Kansas. The Missouri basement is reasonably well known because of drilling for minerals and has been studied by Kisvarsanyi (1974, 1975). Relatively little is known about the Precambrian rocks of Iowa and eastern Colorado, because a smaller number of wells have penetrated the basement there.

Archean time

No rocks of Archean age are known in Area II, although such rocks may underlie parts of northern Iowa because of the proximity of the ancient rocks that are exposed in the Minnesota River Valley (Goldich et al., 1970; Goldich and Hedge, 1974).

Proterozoic time (Interval Occurring 1,600-2,500 m.y. ago)

Only one radiometric age greater than 1,800 m.y. has been reported for any rocks from Area II, and most are 1,700 m.y. or less (Goldich et al., 1966). We have, however, indicated on the chronometric chart (Figure 1) that

both sedimentary and volcanic rocks may have formed as early as 2,000 m.y. ago. This speculation is based upon the presence of silicic metavolcanic rocks and various metasedimentary rocks (schists, quartzites) in the basement of both Kansas and Nebraska. These are associated spacially with gneissoid granitic rocks that have yielded ages of about 1,700 m.y. If metamorphism occurred later than 1,700 m.y. ago, it did not result in lowering of Rb-Sr whole-rock of feldspar ages of at least some of the gneissoid rocks, and we consider it more likely that metamorphism either preceded or accompanied the synkinematic emplacement of the granitic rocks about 1,700 m.y. ago. This event would thus be correlative with the Boulder Creek event which has been well documented in the northern Front Range of Colorado (Peterman and Hedge, 1968; Stern et al., 1971).

Metavolvanic, Metasedimentary, and Foliated Granitic Rocks Formed 1,650-1,800 m.y. ago: Much of Area II is underlain by the gneissoid granitic rocks (Fig. 3) mentioned in the preceding section. Some of these rocks have been determined to be 1,600 to 1,800 m.y. old by either Rb-Sr or U-Pb (zircon) methods (Goldich et al., 1966; Bickford, unpublished data). These rocks are commonly granitic to granodioritic in composition and are characterized by slightly to moderately developed foliation caused by pervasive shearing and cataclasis. Metasedimentary and metavolcanic rocks are distributed throughout the area either in fairly well defined belts or in small patches only a few kilometers in diameter. Metavolcanic rocks that were evidently originally rhyolitic to dacitic are known in western Kansas, northcentral Missouri, and in northern and southwestern Nebraska, but are not as widely distributed as metasedimentary rocks. Metamorphic rocks include fairly abundant muscovite and biotite schist, minor amphibolite, and abundant quartzite; the quartzite forms prominent basement-surface highs in southwestern Nebraska (Lidiak, 1972), to the south on the Central Kansas Uplift (Walters, 1946), and on the Central Missouri High (Kisvarsanyi, 1974). The Sioux Quartzite (age and extent discussed under Area I) extends as far south as extreme northern Nebraska in the subsurface. It is known to rest nonconformably upon the underlying igneous-metamorphic complex, but it is not known whether the patches of metavolcanic and metasedimentary rocks which are known elsewhere throughout Area II lie upon the 1,600-1,800 m.y. old granitic rocks or are older pendants and inclusions within them.

It seems clear that a widespread period of pervasive shearing and cataclasis occurred between 1,800 m.y. ago (the age of the oldest rocks dated) and about 1,480 m.y. ago, the oldest age determined from a widespread suite of non-foliated anorogenic plutons that occur within the older terrane (Goldich et al., 1966; Harrower, 1977; Bickford unpublished data). Since the age of the metavolcanic and metasedimentary rocks relative to the foliated granitic rocks is not known, it cannot be determined whether a single period of pervasive regional metamorphism, reaching amphibolite facies in parts of the area, affected all these rocks, or whether the metasedimentary and metavolcanic rocks were formed by a metamorphic episode earlier than the period of shearing and cataclasis that affected the granitic rocks.

Proterozoic time (Interval Occurring 900-1,600 m.y. ago)

Anorogenic plutonic rocks formed about 1,450-1,480 m.y. ago: Granitic to tonalitic plutons with ages in the range 1,450-1,480 m.y. are known in Nebraska, northern Kansas, and northern Missouri. These rocks are generally

not foliated and thus presumably were intruded into the older terrane after the pervasive shearing event. Because these rocks are not accompanied by associated volcanic rocks in this region, and because they are not deformed, they are assumed to have been emplaced anorogenically. These rocks are evidently a part of the great belt of anorogenic plutons of this age which are known from Labrador to California (Silver et al., 1977; Emslie, 1978). Where they have been well studied at the surface (e.g. Wolf River batholith, Wisconsin; Van Schmus et al., 1975; Anderson and Cullers, 1978; St. Francois Mountains batholith, Missouri; Bickford and Mose, 1975) they are seen to be characterized by rapakivi texture and silicic-alkalic chemistry.

In Nebraska the age of these plutons is known mainly from Rb-Sr measurements of total rock samples, but a U-Pb age of 1,445 ± 15 m.y. has been obtained recently on zircons separated from a core from southwestern Nebraska (Harrower, 1977). Harrower also determined a similar age for zircons from a core in north-central Kansas.

As will be seen in the discussion of Area III, plutons of this type occur to the south in southern Kansas, southern Missouri, and Oklahoma in association with extensive rhyolitic volcanic rocks. There, however, the age of the plutons is about 1,380 m.y. except in southeastern Missouri where plutons and volcanic rocks are about 1,480 m.y. old (Bickford and Mose, 1975).

Anorthosites in southwestern Nebraska: A complex of anorthositic rocks occupies an area of about 400 km^2 in southwestern Nebraska (gabbro on Fig. 3). The rocks range in composition from anorthosite to anorthositic gabbro and have been subjected to cataclasis and to incipient greenschist facies metamorphism. There is no direct radiometric age measurement available for these rocks, but Lidiak (1972) has inferred that they are younger than schists in the area because they lack metamorphism of amphibolite facies that may have occurred about 1,800 m.y. ago, and that they are older than a period of cataclasis and greenschist facies metamorphism that has been inferred to have occurred about 1,200 m.y. ago.

Mafic volcanic and hypabyssal rocks and related arkosic sedimentary rocks associated with the Central North American Rift System: A major belt of mafic volcanic and hypabyssal igneous rocks coincides with pronounced positive magnetic and gravity anomalies in Kansas, Nebraska, and Iowa (King and Zietz, 1971; Woollard, 1943; Lyons, 1950; Thiel, 1956). Flanking basins containing immature sedimentary rocks are associated with negative anomalies on both sides of the belt of mafic rocks. This feature, the Central North American Rift System (Ocola and Myer, 1973; Chase and Gilmer, 1973) can be traced northwards into Minnesota where both the mafic volcanic rocks and the flanking arkosic sedimentary rocks appear at the surface in the Lake Superior region. There the age of the mafic volcanism has been determined to be about 1,100 m.y. (Goldich et al., 1961; Silver and Green, 1963, 1972; Goldich et al., 1966; Chaudhuri and Faure, 1967; Van Schmus, 1971); a well sample from Nebraska has also yielded a K-Ar whole rock age of 990 m.y. (Goldich et al., 1966). The continuity of these rocks in a belt that is more than 1,500 km long and about 65 km wide implies that they formed about the same time during a late Proterozoic rifting event.

In Nebraska the mafic igneous rocks include both hypabyssal types and extrusive basalts, and similar types have been observed in Kansas. The relatively small number of basement wells in Iowa precludes much detailed

knowledge of these rocks there, but both mafic igneous rocks and arkosic sedimentary rocks have been encountered along the trend of the geophysical anomalies. Sedimentary rocks in both Kansas and Nebraska are mostly arkosic, but subarkose, argillaceous wackes, argillaceous wackes, and reddish siltstones are also present. In Kansas, Scott (1966) has called these rocks the Rice Formation.

Metamorphism: Lidiak (1972) has noted the widespread occurrence of metamorphism in greenschist facies in rocks in the Nebraska basement, and has inferred that this event occurred about 1,170 m.y. ago on the basis of numerous K-Ar and Rb-Sr ages of micas that fall within about ± 100 m.y. of this age. That these mica ages record a metamorphic event is indicated by the fact that many of them are from rocks for which whole-rock or feldspar ages are significantly greater.

Lidiak (1972) has also observed low grade metamorphic mineral assemblages in the basaltic rocks of the Central North American Rift System. These assemblages, including pumpellyite, laumontite, epidote, and chlorite, are indicative of metamorphism under conditions commonly attributed to simple burial metamorphism.

Area III: Southern Missouri, Southern Kansas, Oklahoma, and Northwestern Arkansas

Area III (Fig. 4) is underlain almost entirely by an extensive terrane of silicic volcanic rocks and associated epizonal and mesozonal granitic plutons. These rocks were formed in the interval 1,300-1,500 m.y. ago; rocks older than about 1,500 m.y. are not known anywhere in the area. Moreover, Precambrian mafic and intermediate igneous rocks are quite rare and, except for small areas in Missouri and Kansas, sedimentary or metasedimentary rocks are not known. The igneous rocks of the Wichita Mountains in south-central Oklahoma (Fig. 4) include basalt, rhyolite, epizonal granite plutons, and a large body of gabbroic rocks (Ham et al., 1964). Most of these rocks yield K-Ar and Rb-Sr ages in the range 510-530 m.y. (Tilton et al., 1962; Muehlberger et al., 1966; Burke and others, 1969) and thus constitute an anomalously young part of the crystalline curst in this area.

Proterozoic time (Interval Occurring 900-1,600 m.y. ago

Formation of rhyolitic to dacitic volcanic rocks and associated epizonal plutons 1,485 to 1,350 m.y. ago: One of the major events in the formation of the central part of the continent occurred during the interval 1,485-1,350 m.y. ago when an extensive terrane of silicic volcanic and plutonic rocks formed. This terrane extends across the midcontinent region from western Ohio at least into the Oklahoma Panhandle; similar rocks occur in the Texas Panhandle and New Mexico, but these appear to be somewhat younger. This terrane is notable for its scarcity of intermediate to mafic rocks.

In the St. Francois Mountains of southeast Missouri, about 900 km^2 of an extensive terrane of alkali rhyolitic ash-flow tuff, trachyte, trachyandesite, and a number of granitic plutons are exposed (Tolman and Robertson, 1969; R. E. Anderson, 1970; Berry and Bickford, 1972; Kisvarsanyi, 1972). This igneous terrane underlies an area of at least 40,000 km^2 in southeast Missouri (Kisvarsanyi, 1974). The exposed part of this terrane includes part of the volcanic roof that is several km thick and a complex of subvolcanic and

epizonal plutons. Plutonic rocks are exposed principally in the northeastern part of the area, whereas to the southwest, volcanic rocks are exposed, suggest that some plutons are tilted to the southwest (Bickford et al., 1977). Contacts between the plutons and the volcanic roof, as well as chemical, mineralogical, and textural variations within the plutons, indicate that some of them are sheet-like. Some plutons, however, are cylindrical and cone-sheet like in form, as suggested by subsurface and geophysical data (E. B. Kisvarsanyi, unpublished). This terrane has clearly not been subjected to penetrative deformation.

The exposed rocks of the St. Francois terrane have been dated by Rb-Sr whole-rock and U-Pb (zircon) methods by Bickford and Mose (1975). The Rb-Sr system has evidently been disturbed, for the ages reported range from about 1,380 m.y. to as low as 1,200 m.y., and there are several contradictions between the age data and field relations. U-Pb measurements on zircons, however, yield consistent ages of about 1,485 m.y. for four major plutons and for one of the major volcanic units; one small sill or stock, the Munger Granite Porphyry, yields a U-Pb zircon age of about 1,385 m.y. and may indicate a younger igneous event in this area. A granite core from a buried part of the St. Francois terrane also yields a U-Pb age of 1,485 m.y. (Bickford, unpbulished data).

Rocks entirely similar to those of the St. Francois terrane extend in the subsurface across southern Missouri and northern Arkansas into southern Kansas, Oklahoma, and the Texas Panhandle. Studies of these rocks, mainly from cuttings and cores returned from deep drilling, include those of Denison (1966) in northeastern Oklahoma, southeastern Kansas, and southwestern Missouri; Muehlberger et al. (1967) over a large region including parts of Texas and New Mexico as well as the region considered here; Kisvarsanyi (1974) in Missouri; and Bickford et al. (1979) in Kansas.

The ages of these rocks have been studied in northeastern Oklahoma and southwestern Missouri by Muehlberger et al. (1966), Denison et al. (1969), and Bickford and Lewis (1979), and in the Kansas basement by Bickford (unpublished data). U-Pb age determinations for zircons from the Spavinaw Granite, which is exposed in northeastern Oklahoma and from a granite in the subsurface in southeastern Kansas (Bickford, unpublished data), indicate that they are 1,375 m.y. old. These ages are in reasonable agreement with the Rb-Sr isochron age of about 1,300 m.y. determined by Denison et al. (1969) from subsurface samples in northeastern Oklahoma.

<u>Mesozonal granite rocks along the Nemaha Ridge in Kansas and Oklahoma, and in the eastern Arbuckle Mountains, Oklahoma</u>: A terrane of mesozonal granitic rocks is known in southern Kansas along the northeast-southwest trend of the Nemaha Ridge (Bickford et al., 1979), and extends southwesterly into Oklahoma at least as far as Oklahoma City (Denison, 1966). The age of these rocks is not well known, but their mesozonal character and their occurrence along the Nemaha Ridge suggests that they are somewhat deeper portions of the continental crust that were brought up by fault movements on the Nemaha structure and exposed by erosion prior to Late Cambrian sedimentation.

The only other place in Area III where more deep-seated igneous rocks are known is in the Eastern Arbuckle Mountains of southeastern Oklahoma

(Ham et al., 1964). There, four extensive plutons are exposed in the core of the Tishomingo-Belton anticline (Denison, 1973). Rocks exposed include an unnamed granodiorite, the Troy Granite, the Tishomingo Granite, and the Blue River gneiss. The Troy Granite intrudes the unnamed granodiorite and is intruded by the Tishomingo Granite; the Blue River gneiss is intruded by the Tishomingo Granite, but its age relationships with the Troy Granite and the unnamed granodiorite are not known because the Tishmoningo Granite separates it from those rock bodies. All these rocks are medium to coarse-grained and have petrographic features suggesting mesozonal emplacement. Bickford and Lewis (1979) have determined the U-Pb ages of zircons from the Tishomingo Granite (1,374 ± 15 m.y.), the Troy Granite (1,399 ± 95 m.y.), and the Blue River gneiss (1,396 ± 40 m.y.). The rocks are therefore the mesozonal age equivalents of the epizonal granophyres and rhyolites in southern Kansas and northeastern Oklahoma.

Several types of dikes intrude the granitic rocks of the eastern Arbuckle Mountains. The most common dikes are diabasic, whereas dikes of microgranite porphyry, granite, and rhyolite porphyry are less common. On the basis of unpublished age determinations it appears that some of the diabase dikes and the granite and microgranite porphyry dikes are approximately the same age as their granitic host rocks, about 1,350-1,400 m.y.; the rhyolite porphyry dikes and the other diabase dikes are of Cambrian age. All the dikes have a strongly developed preferred strike direction near N60°W, which is parallel to the major Pennsylvanian deformational axes.

Phanerozoic time (Paleozoic Era, Cambrian Period)

The igneous rocks of the Wichita Mountains consist of a bimodal suite of silicic and gabbroic rocks. The silicic rocks, consisting of epizonal granite plutons and rhyolite, and some of the gabbroic rocks have yielded ages in the range 510 to 520 m.y. (Tilton et al., 1962; Muehlberger et al., 1966). Paleomagnetic data (Roggenthen et al., 1976) and geologic considerations (Powell and Phelps, 1977) have suggested that the oldest rock unit, the layered series of the Raggedy Mountain Gabbro, is of Precambrian age. The K-Ar ages of these rocks, however, suggest a Cambrian age (Burke et al., 1969), and the age must be considered uncertain. The Raggedy Mountain Gabbro is the only large layered gabbroic mass exposed in the continental interior.

The geological relations and structural framework for southern Oklahoma that were outlined by Ham et al. (1964) appear to be essentially correct. However, the rhyolite terrane in extreme southwestern Oklahoma, that was considered to be of Cambrian age by Ham et al., is now thought to be an outlier of the Panhandle rhyolites of Precambrian age (see discussion in Area IV) on the basics of unpublished age determinations. The Tillman Metasedimentary Group is most probably Precambrian as suggested by Muehlberger et al. (1967), although parts of this unit may indeed be of Cambrian age as argued by Ham et al.

Area IV: Texas and Eastern New Mexico

This area was the subject of the first successful study of the buried basement rocks of a large region. Flawn (1956), was able to show that consistently mappable units could be recognized over large areas by the

petrographic study of well samples. There were virtually no isotopic ages available at that time, and the sequence of events and relative ages of the units were later modified when ages became available. The dating of both surface and subsurface samples by Wasserburg et al. (1962) and Muehlberger et al. (1966) made possible the determination of the sequence of events. Later, largely unpublished geochronological work on well samples has refined this timing of igneous and metamorphic activity, but no major modifications of the unpublished data are justified at this time.

Proterozoic time (Interval Occurring 1,600-2,500 m.y. ago)

Torrance metamorphic terrane and "older granitic gneisses": The oldest isotopic ages from the area shown in Figure 5 have been reported from eastern New Mexico where Muehlberger et al. (1966) determined Rb-Sr ages in excess of 1,600 m.y. for a whole-rock sample and for a feldspar from granitic gneisses. Micas from both of the rock samples studied yielded metamorphic ages of about 1,350 m.y. The granitic gneisses are associated with metasedimentary and metavolcanic rocks that are probably equivalent to the sequence found in outcrop along the Los Pinos-Manzano trend (Stark and Dapples, 1946; Stark, 1956). Long (1972) reported ages of "about 1,600 m.y. or older" for metavolcanic rocks northward along this trend. The relationship between gneisses and the supracrustal rocks cannot be determined on the basis of the available information, but the mature character of the metasedimentary rocks suggests they were originally shelf deposits upon sialic crust. These two units (the Torrance metamorphic terrane, and the "older granitic gneisses" of Muehlberger et al., 1967) have been extended with considerable trepidation in the subsurface on the basis of petrography.

Proterozoic time (Interval Occurring 900-1,600 m.y. ago)

Rocks formed 1,200 to 1,400 m.y. ago: Granitic gneisses, found through much of southeastern New Mexico, were grouped into the Chaves granitic terrane by Muehlberger et al. (1967). It now seems desirable to extend this unit into the Texas Panhandle on the basis of scattered unpublished age determinations and petrographic similarities of rocks encountered. These rocks have yielded ages in the 1,400 m.y. range, the oldest ages known in Texas. Some of the ages measured reflect periods of metamorphism, but others are probably close to the time of original intrusion. Differentiation of rock units within the area is not justified on the basis of the available data.

The Sierra Grande terrane of northeastern New Mexico and the Texas Panhandle (Muehlberger et al., 1967) is the oldest of the large areas underlain by anorogenic granite. These rocks are distinguished from older units by the absence of metamorphic features and by their more silicic chemical composition. Rb-Sr data from several published and unpublished determinations of whole rocks, feldspars, and micas form an isochron indicating an age of about 1,300 m.y. Apparent ages on some rhyolites that are petrographically and geographically inseparable from the younger Panhandle volcanic terrane indicate that volcanism also occurred during this period.

The metamorphic rocks called the Red River mobile belt by Flawn (1956) and the Tillman Metasedimentary Group by Ham et al. (1964) remain an unresolved problem. Rocks grouped under these names have yielded metamorphic

ages from 1,380 m.y. to about 1,000 m.y. (Wasserburg et al., 1962; and Denison, unpublished data). The rocks around the Muenster Arch are now believed to be related in time of metamorphism to those in the Llano province. Rocks to the west, along the Red River Uplift, are older, but their relationship to surrounding rocks is not known.

Rocks formed 1,000 to 1,200 m.y. ago: A sequence of rhyolites and comagmatic granites was extruded and emplaced over much of the Texas Panhandle and far eastern New Mexico about 1,180 ± 20 m.y. ago. The age of this extensive rhyolite field, the Panhandle volcanic terrane, is known from Rb-Sr whole rock isochron studies. It covers more than 52,000 km^2 despite considerable diminution by erosion and partial covering by younger rocks. Many of the rhyolites preserve delicate ignimbritic features. The associated granites, grouped into the Amarillo granite terrane are typical hypersolvus epizonal intrusives; micrographic textures are common. The rocks are leucocratic and composed almost entirely of quartz and perthite.

A wide variety of Precambrian metamorphic and igneous rocks are exposed in the Llano Uplift of central Texas. These and their subsurface equivalents are here called the Llano province. This suite of rocks can be traced in the subsurface with some degree of confidence nearly 300 km north of the uplift. The boundary to the west is difficult to define because of sparse control and other complications. To the south and east the Precambrian is buried beneath thick Paleozoic rocks of the Ouachita foldbelt. The geology of the Precambrian rocks in the Llano Uplift has been summarized by Clabaugh and McGehee (1962) and Garrison et al. (1978). The geochronology of certain of the rock units has been studied by Zartman (1964, 1965), Delong and Long (1976), and Garrison et al. (1978).

Three major rock units comprise the Llano province. The oldest of two metamorphic units is the Valley Spring Gneiss. It is overlain by the Packsaddle Schist which has a measured thickness of 7,330 m and is composed of hornblende, graphite, biotite, muscovite, and actinolite schists; marble and various leptites also make up a substantial part of the Packsaddle section. These two units form the country rock for the third unit, which is composed of a variety of granitic intrusions.

The Valley Spring Gneiss has yielded an age of about 1,160 ± 30 m.y. (Zartman, 1965). Foliated granitic intrusive rocks (Big Branch Gneiss and Red Mountain Gneiss) that cut the Valley Spring and lower Packsaddle have yielded a Rb-Sr isochron age of 1,167 ± 12 m.y. (Garrison et al., 1979, in press). These results suggest that the Packsaddle Schist was deposited during the relatively narrow time span between 1,155 and 1,190 m.y. ago. All these older rocks were intruded by massive plutonic granites (e.g., the Town Mountain Granite) about 1,060 m.y. ago, near the end of an episode of regional metamorphism (Zartmen, 1964).

The Van Horn area of western Texas is underlain by a wide variety of metaigneous and metasedimentary rocks (King and Flawn, 1953; King, 1965). Dating of these rocks, the Carrizo Mountain Group, indicates a period of regional metamorphism about 1,000 m.y. ago with the development of pegmatites (see Denison et al., 1971 for a review). The age of deposition of the Carrizo Mountain Group has not been clearly defined. The metarhyolites in the Van Horn area may not be as old as the calculated Rb-Sr age of about 1,280 m.y.

(Denison and Hetherington, 1969), but they appear to be distinguishably older than the rhyolites in the Franklin Mountains on the basis of comparative Rb-Sr and $^{207}Pb/^{206}Pb$ ages (see also Wasserburg et al., 1962).

The DeBaca terrane and the Swisher diabasic terrane appear to be isochronous. Muehlberger et al. (1967) and Denison and Hetherington (1969) have reviewed previous information and correlations from the outcrop into the subsurface. Outcrops of these metasedimentary and basaltic rocks are found in the northern Van Horn area, the Franklin Mountains, and in small-outcrop areas northward in New Mexico. In far western Texas the metasedimentary rocks are in part demonstrably of marine origin. Northward into the subsurface the rocks become increasingly arkosic and are probably non-marine. Basaltic rocks associated with the metasedimentary units are more common northward.

The time of sedimentation has not been strictly determined. In the Franklin Mountains metasedimentary rocks are conformably overlain by rhyolites and intruded by granites that have ages near 1,000 m.y. It seems probable that the original sedimentary rocks were deposited just prior to the extrusion of the rhyolites, perhaps in the interval between 1,000 and 1,100 m.y. ago.

The Franklin Mountains have some exceptionally fine exposures of Precambrian igneous and metamorphic rocks (Harbour, 1972). Nearly 460 m of rhyolite flows overlie metasedimentary rocks of the DeBaca terrane and are in turn intruded by diverse granitic stocks and sills.

The ages of rhyolites and granites in the Franklin Mountains all fall into a rather narrow range around 1,000 m.y. (Denison and Hetherington, 1969). These ages indicate that this is the youngest of the Precambrian rhyolite-epizonal granite associations. These igneous rocks appear to be rather limited in areal extent. Small isolated outcrops are found about 100 km to the east and some 150 km to the north of the Franklin Mountains. This igneous activity evidently did not cover as great an area as the older rhyolite fields. Perhaps a smaller volume of magma erupted; but the rocks may also have been removed by erosion, or they may extend to the south into northcentral Mexico where no information is available.

Proterozoic time (Interval Occurring from 600 to 900 m.y. ago)

Metarhyolite of Devils River Uplift: A few wells along the Devils River Uplift southwest of the Llano Uplift in Texas have penetrated metarhyolite. The few isotopic measurements available from these rocks suggest late Precambrian or Early Cambrian ages (Nicholas and Rozendal, 1975; Denison et al., 1977). The rhyolites are underlain in part by massive granitic rocks about 1,250 m.y. old that have been penetrated in only one well.

The best interpretation of the isotopic data is that the rhyolites were extruded not less than 725 m.y. ago. The extent of this unit and its significance is not known because of sparse control from drill holes. It would appear to be the youngest Precambrian igneous rock found in the area. Micas from the metarhyolites yield mid-to-late Paleozoic ages, indicating that they have been strongly affected by younger metamorphism.

The Van Horn Sandstone: This sedimentary rock unit may be late Precambrian or earliest Paleozoic in age. It is geographically restricted to

an area north of Van Horn in far western Texas. McGowen and Groat (1971) have shown that the unit was deposited as an alluvial fan upon strongly folded, faulted, and dissected Precambrian rocks that were metamorphosed about 1,000 m.y. ago. The Van Horn Sandstone is overlain by the Bliss Sandstone of Ordovician age. Thus the Van Horn must have been deposited between about 1,000 and 480 m.y. ago. The available data does not permit extension of this unit into the subsurface.

Phanerozoic time (Paleozoic Era, Cambrian Period)

Areas underlain by the subsurface extension of the Wichita Province igneous rocks (see discussion in Area III) are found in adjacent parts of the Texas Panhandle. Muehlberger et al. (1966) reported a rhyolite yielding an apparent Cambrian age in the central Texas Panhandle, well away from the principal exposures and subsurface extent in southern Oklahoma.

Area V: Eastern Midcontinent

Area V(Fig. 6) is underlain by two widespread basement rock terranes. In the eastern part of the area is the subsurface extension of the Grenville Province of Canada. To the west of the Grenville Province is a terrane that consists predominantly of granite, rhyolite, trachyte, basalt, and related rocks of middle and late Proterozoic age.

Proterozoic time (Interval Occurring 900-1,600 m.y. ago)

Granite-rhyolite terrane: Southern Wisconsin, Illinois, Indiana, and the western parts of Ohio, Kentucky, and Tennessee are underlain by a vast terrane of essentially unmetamorphosed rhyolitic and trachytic volcanic rocks and epizonal granitic rocks. These rocks represent an apparent continuation of the anorogenic terrane to the north in central Wisconsin. Van Schmus (1978) found that the Precambrian basement in central Wisconsin consists in part of 1,780-1,800 m.y. old rhyolitic ignimbrites, granophyric granites, and porphyritic granites intruded by 1,500 m.y.-old rapakivi-type granites.

The anorogenic terrane is extensively developed in the eastern and south-central midcontinent. It apparently extends from central Wisconsin southwestward to northern New Mexico and Arizona (Bass, 1960; Zietz et al., 1966; Muehlberger et al., 1967; Bickford and Mose, 1975; and others).

The granite-rhyolite terrane of the eastern midcontinent is characterized by an overall homogeneity and relatively subdued magnetic anomaly pattern. suggesting that the area forms a distinct crustal unit of essentially undeformed volcanic rocks and mainly epizonal granitic rocks. The western boundary of the terrane is drawn near the Iowa-Illinois state line along a distinct change in magnetic anomaly pattern (Zietz et al., 1966).

The apparent age and petrographic character of the granite-rhyolite terrane was described by Lidiak et al. (1966). Granitic igneous activity appears to have occurred between 1,200-1,500 m.y. ago. Most of the available age determinations, however, are Rb-Sr and K-Ar dates on micas, and thus they may be minimum ages that have been reduced by later igneous or metamorphic activity. An unpublished Rb-Sr measurement on a micrographic granite from Fulton County, northern Indiana, yielded an apparent age of 1,480±40 m.y. This age corresponds to the age of the Wolf River batholith of central Wisconsin (Van Schmus et al., 1975) and suggests that granitic igneous activity was widespread at this time. The age of the volcanism is also uncertain. Apparent ages from rhyolite and trachyte are between 1,250-1,350 m.y. (Lidiak et al., 1966). However, the volcanism may be older and date from 1,500 m.y. ago and possibly 1,750±10 m.y. ago.

Sedimentary rocks: Unmetamorphosed to slightly metamorphosed sedimentary rocks of pre-Late Cambrian age occur in widely spaced wells in the eastern midcontinent. At least some of the rocks are of middle Proterozoic age. For example, the Baraboo Quartzite and related rocks of south-central Wisconsin (Dott and Dalziel, 1972) were deposited later than 1,760 m.y. ago. The Baraboo Quartzite and the previously described Sioux Quartzite of South Dakota are probably correlative and represent widespread sedimentation. Similarly, the quartzites and slates in the subsurface of southern Wisconsin (Thwaites, 1931) may have been deposited during this period of time.

Basaltic rift zones: A series of north to northwest-trending basement rift zones occurs in the granite-rhyolite terrane (Fig. 6). The rifts, which are probably underlain by mafic igneous rocks, are delineated mainly by linear gravity and magnetic anomalies and by sparse basement well control. None of these rocks have been dated, but they are tentatively assigned a middle Keweenawan age (1,000-1,200 m.y.) because of their general similarities to rocks of the Central North American Rift System.

The best documented of these inferred rifts occurs in the Michigan basin. Hinze et al. (1975) have made a detailed study of the linear gravity and magnetic anomalies and concluded that they represent a middle Keweeawan rift zone. A recent deep test drilled near the center of the basin encountered mafic igneous rocks beneath a thick section of red clastic sedimentary rocks (Bradley and Hinze, 1976; Van Der Voo and Watts, 1976), thus supporting the rift zone interpretation.

The linear gravity high in eastern Indiana and western Ohio is also regarded as indicating a rift zone. Three of the six wells to basement along this structure bottomed in basalt; the other three in felsic igneous rocks. Immediately to the south of the rift two micrographic granites have Rb-Sr ages on feldspars of about 1,125 m.y. The relation of these felsic rocks to the basalts is not established, but the ages suggest that felsic igneous activity also occurred during the development of the rift zones in middle Keweenawan time.

Northwest-trending gravity and magnetic highs outline an inferred belt of basalt or gabbroic igneous rocks in eastern Illinois. Rudman et al. (1972) recognized an area of magnetic and gravity highs immediately to the south in southwestern Indiana and concluded that the area is underlain by basalt. There is presently no basement well control for this proposed structure in Illinois or its possible extension into Indiana.

The inferred north-trending rift zone in Kentucky, Tennessee, and Alabama also coincides with gravity and magnetic highs. The geophysical anomalies suggest the presence of a thick sequence of mafic igneous rocks.

Rift-related sedimentary rocks: Unmetamorphosed sedimentary rocks that are apparently associated with the basaltic rift zones have been encountered in the Michigan Basin (Bradley and Hinze, 1976), western Ohio, and northern Kentucky. These rocks occur beneath Upper Cambrian strata and are of probable late Proterozoic age. They are inferred to have been deposited during formation of the rift zones.

Other sedimentary rocks of pre-Late Cambrian age are also present in western Tennessee and Kentucky and in southern Illinois near the center of the Illinois Basin. They are apparently not associated with basalts and may be as old as latest Proterozoic.

Subsurface Grenville Province: The Grenville Province of Canada extends into the subsurface of the United States near the western end of Lake Erie along a series of prominent south-trending gravity and magnetic highs. These anomalies appear to cut, and thus post-date the northwest-trending anomalies associated with the rift zone in the Michigan Basin (Hinze et al., 1975). The south-trending anomalies continue into Ohio and form a sharp gradient, separating a series of positive magnetic and gravity highs on the east from broader, less intense anomalies on the west (Zietz et al., 1966).

Petrographic study and age determinations (Lidiak et al., 1966) show that this sharp gradient coincides with the boundary between a granite-metamorphic complex on the east and an older, less deformed terrane on the west. East of the boundary in eastern Ohio and West Virginia, the basement rocks consist mainly of mica and hornblende schist and gneiss, two-feldspar granite, and less commonly marble and calc-silicate rock. Most of the metamorphic rocks are of amphibolite grade.

Age determinations on micas from gneiss, schist, and granite in parts of Michigan, Ohio, Pennsylvania, and West Virginia are in the range 800-1,000 m.y. These ages are in good agreement with mica ages determined from the Grenville Province in Canada. Most of the mica ages do not date the main period of orogeny, but reflect instead later tectonic or thermal disturbance and probably deep burial and subsequent uplift. The last main period of metamorphism occurred about 1,100 my.y ago (e.g. Lidiak et al., 1966). More recent studies by Krough and Davis (1969) indicate that regional metamorphism and formation of paragneiss in the northwest Grenville area occurred between 1,500 and 1,900 m.y. ago. Other periods of Grenville regional metamorphism occurred about 1,300 and 1,100 m.y. ago.

The Grenville Front extends southward into Kentucky and Tennessee (Lidiak and Zietz, 1976). The predominant rock types east of the front are granite gneiss, two-feldspar granite, medium-grade metamorphic rock, and anorthosite. Trachyte, rhyolite, basalt, and weakly metamorphosed sedimentary rocks are the characteristic rocks west of the front. Locally felsic volcanic rocks also occur immediately east of the front. The Grenville Front is tentatively shown extending into Alabama on Figure 5.

The only available isotopic age determinations on the subsurface rocks of the Grenville province are the previously mentioned K-Ar and Rb-Sr ages on micas. Consequently, the period of periods of sedimentation, anorthosite intrusion, and granitic plutonism that are shown on the chronometric chart have been inferred. They are based mainly on regional correlations and extrapolations from outcrops.

Metallogenic Significance of the Precambrian Basement

Better understanding of the Precambrian geology of the Central Interior Region is a key to understanding the evolution and distribution of its resource systems. The shallow volcanic-plutonic complexes are potentially the most important tectonic and metallogenic units of the region. The St. Francois terrane of southeastern Missouri constitutes an Fe metallogenic province, and has been the source of Fe production for more than 150 years. Kiruna-type Fe (apatite) and Fe-Cu deposits, some of them rare-earth enriched, are associated with the silicic volcanic rocks of the terrane. Marginal Mn mineralization occurs in the volcanic rocks, hypo-xenothermal veins of W-Pb-Ag-Sn occur in at least one of the plutonic bodies; and late stage two-mica granites of the terrane are among the most uraniferous granites of North America (Malan, 1972).

The metallogenesis of the volcanic-plutonic complexes, as suggested by observations in the St. Francois terrane, is intimately related to the complex magmatic-tectonic processes which produced this extensive anorogenic suite of rocks. Two lines of metallogenic evolution are indicated and have the potential for enrichments in ore deposits: (1) the ferrous metals, related to alkaline intermediate magmatism, and (2) W, Ag, Sn, Pb, U, Th, and F in the late granites (G. Kisvarsanyi, 1976).

The metallogenesis of the older metamorphic basement is not known because of lack of outcrops and no proven ore bodies. By analogies with Canadian Shield provinces, however, it may contain complex and varied mineral deposits. The resource potential in the basement complex of Missouri has recently been evaluated on the basis of drill-hole data (G. and E. B., Kisvarsanyi, 1977). Among the most interesting possibilities are the layered mafic intrusions which have a potential for Fe-Ni-Cu-Co and Pt-Cr-Ti mineralization. The Central North American Rift System is a favorable site for rift-related metallogeny.

Another important metallogenic aspect of the Precambrian basement is its tectono-morphologic control on the emplacement and localization of ore bodies in the overlying sedimentary rocks. Major mineral districts in Missouri, Oklahoma, Kansas, and Illinois are located over Precambrian topographic and structural highs and ancient fracture zones (Snyder, 1970; G. Kisvarsanyi, 1977). While the metals may have been derived from multiple sources, at least some of the metals may have been recycled from a Precambrian source and redistributed into flanking sedimentary basins.

As near-surface resources are continually being depleted, the vast resource potential inherent in the buried basement rocks is becoming of greater interest, particularly where depth to basement is not prohibitive to mining.

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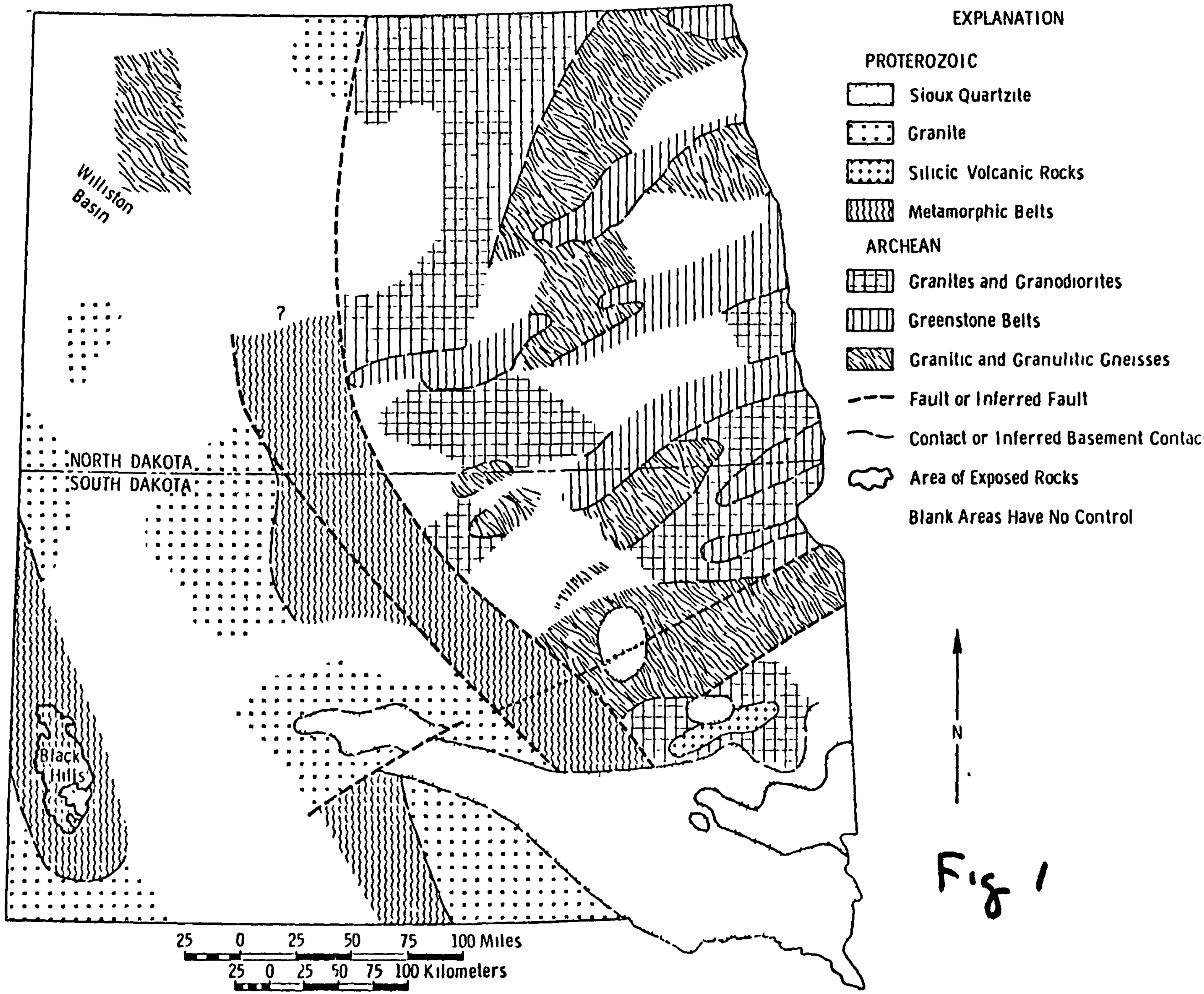

EXPLANATION
PROTEROZOIC
Sioux Quartzite
Granite
Silicic Volcanic Rocks
Metamorphic Belts
ARCHEAN
Granites and Granodiorites
Greenstone Belts
Granitic and Granulitic Gneisses
Fault or Inferred Fault
Contact or Inferred Basement Contact
Area of Exposed Rocks
Blank Areas Have No Control
Williston Basin
NORTH DAKOTA
SOUTH DAKOTA
Black Hills
?
N
25 0 25 50 75 100 Miles
25 0 25 50 75 100 Kilometers

Fig 1

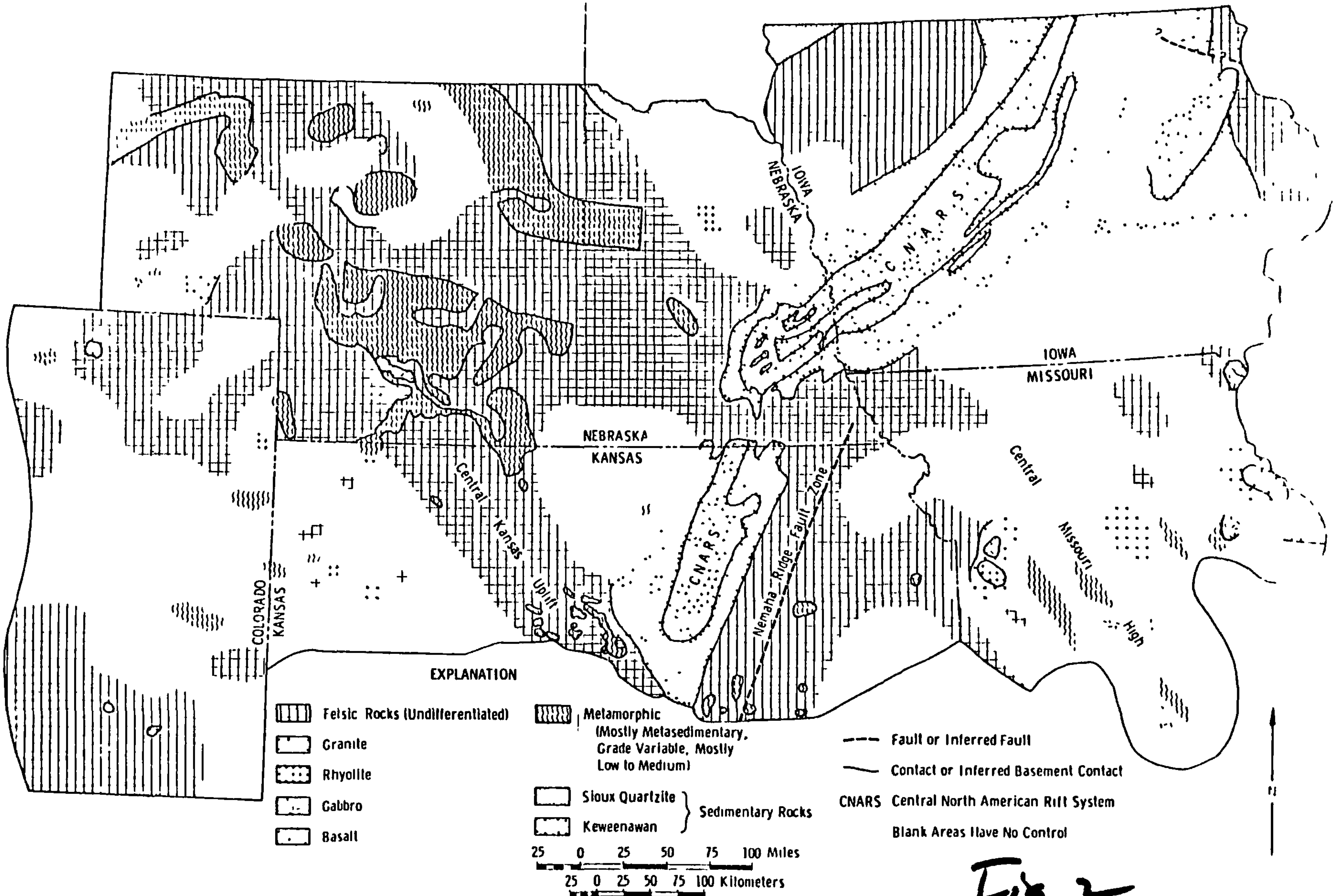

IOWA
NEBRASKA
C N A R S
IOWA
MISSOURI
NEBRASKA
KANSAS
Central Kansas Uplift
CNARS
Nemaha Ridge Fault Zone
Central Missouri High
COLORADO
KANSAS
EXPLANATION
Felsic Rocks (Undifferentiated)
Granite
Rhyolite
Gabbro
Basalt
Metamorphic (Mostly Metasedimentary, Grade Variable, Mostly Low to Medium)
Sioux Quartzite
Keweenawan
Sedimentary Rocks
Fault or Inferred Fault
Contact or Inferred Basement Contact
CNARS Central North American Rift System
Blank Areas Have No Control
25 0 25 50 75 100 Miles
25 0 25 50 75 100 Kilometers

Fig 2

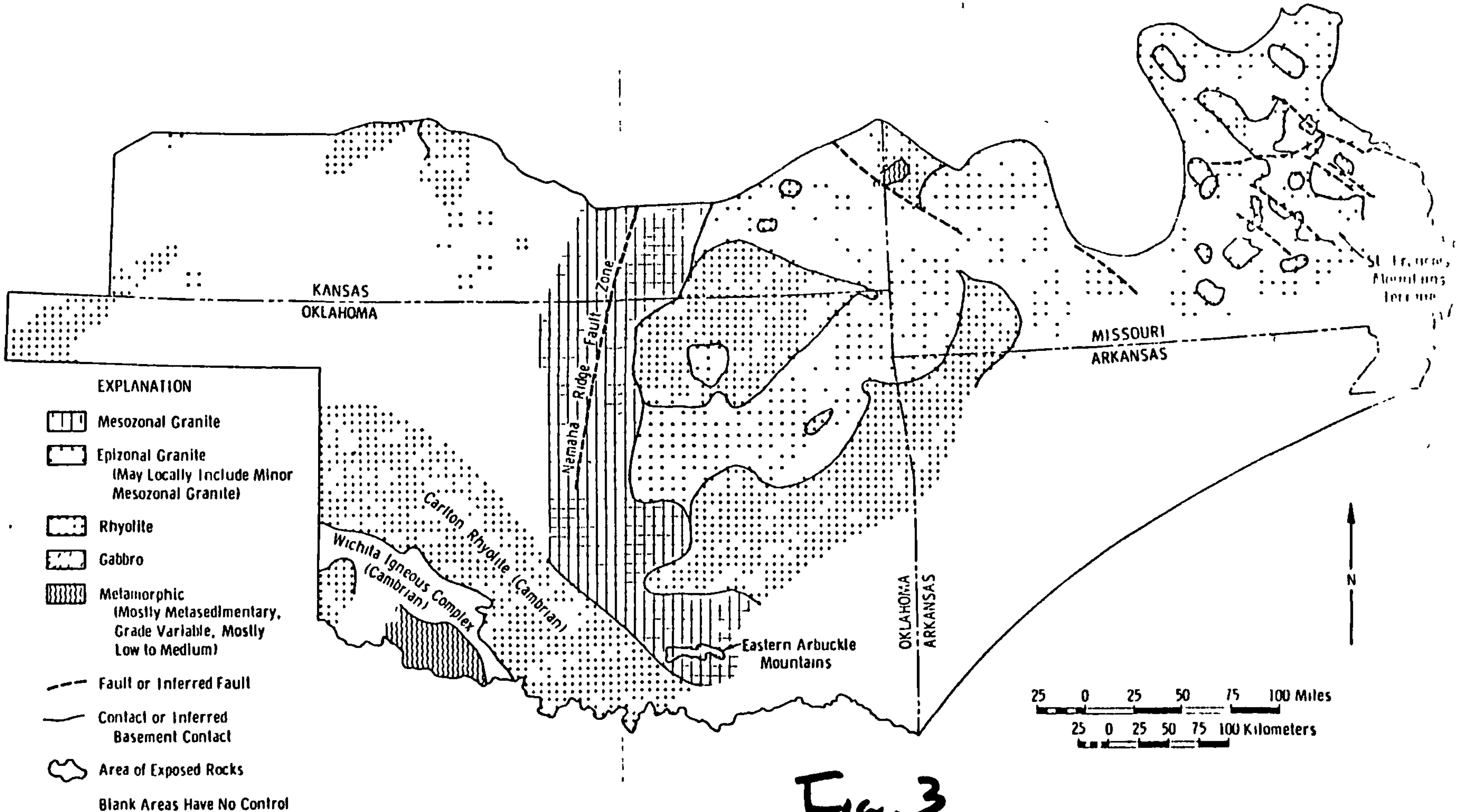

KANSAS
OKLAHOMA
MISSOURI
ARKANSAS
OKLAHOMA
ARKANSAS
Nemaha Ridge Fault Zone
Carlton Rhyolite (Cambrian)
Wichita Igneous Complex (Cambrian)
Eastern Arbuckle Mountains
N
25 0 25 50 75 100 Miles
25 0 25 50 75 100 Kilometers
EXPLANATION
Mesozonal Granite
Epizonal Granite (May Locally Include Minor Mesozonal Granite)
Rhyolite
Gabbro
Metamorphic (Mostly Metasedimentary, Grade Variable, Mostly Low to Medium)
Fault or Inferred Fault
Contact or Inferred Basement Contact
Area of Exposed Rocks
Blank Areas Have No Control

Fig. 3

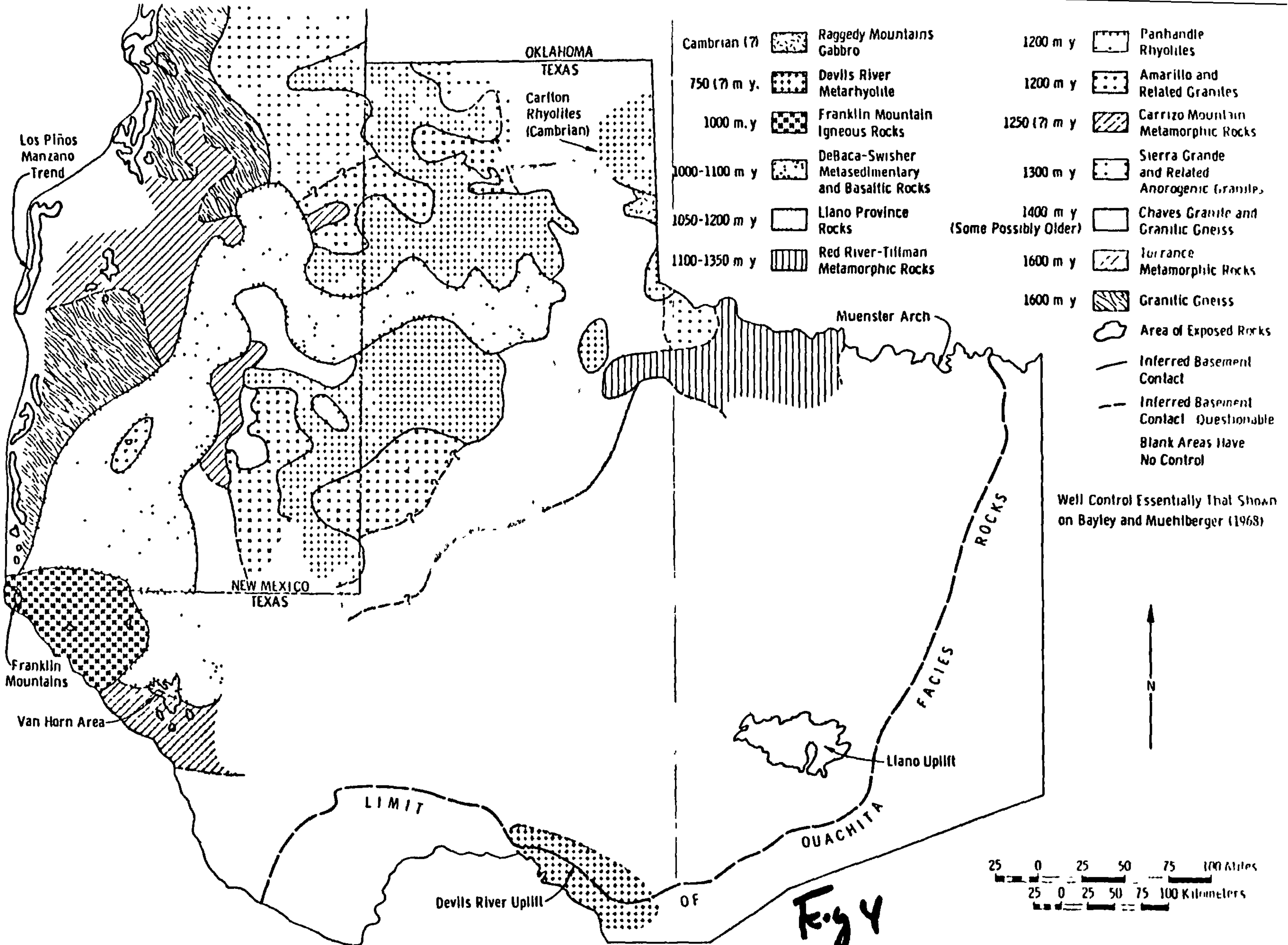

OKLAHOMA
TEXAS
Carlton Rhyolites (Cambrian)
Los Piños Manzano Trend
NEW MEXICO
TEXAS
Franklin Mountains
Van Horn Area
Muenster Arch
Llano Uplift
Devils River Uplift
LIMIT OF OUACHITA FACIES ROCKS
Cambrian (?) Raggedy Mountains Gabbro
750 (?) m y. Devils River Metarhyolite
1000 m.y Franklin Mountain Igneous Rocks
1000-1100 m y DeBaca-Swisher Metasedimentary and Basaltic Rocks
1050-1200 m y Llano Province Rocks
1100-1350 m y Red River-Tillman Metamorphic Rocks
1200 m y Panhandle Rhyolites
1200 m y Amarillo and Related Granites
1250 (?) m y Carrizo Mountain Metamorphic Rocks
1300 m y Sierra Grande and Related Anorogenic Granites
1400 m y (Some Possibly Older) Chaves Granite and Granitic Gneiss
1600 m y Torrance Metamorphic Rocks
1600 m y Granitic Gneiss
Area of Exposed Rocks
Inferred Basement Contact
Inferred Basement Contact Questionable
Blank Areas Have No Control
Well Control Essentially That Shown on Bayley and Muehlberger (1968)
N
25 0 25 50 75 100 Miles
25 0 25 50 75 100 Kilometers

Fig 4

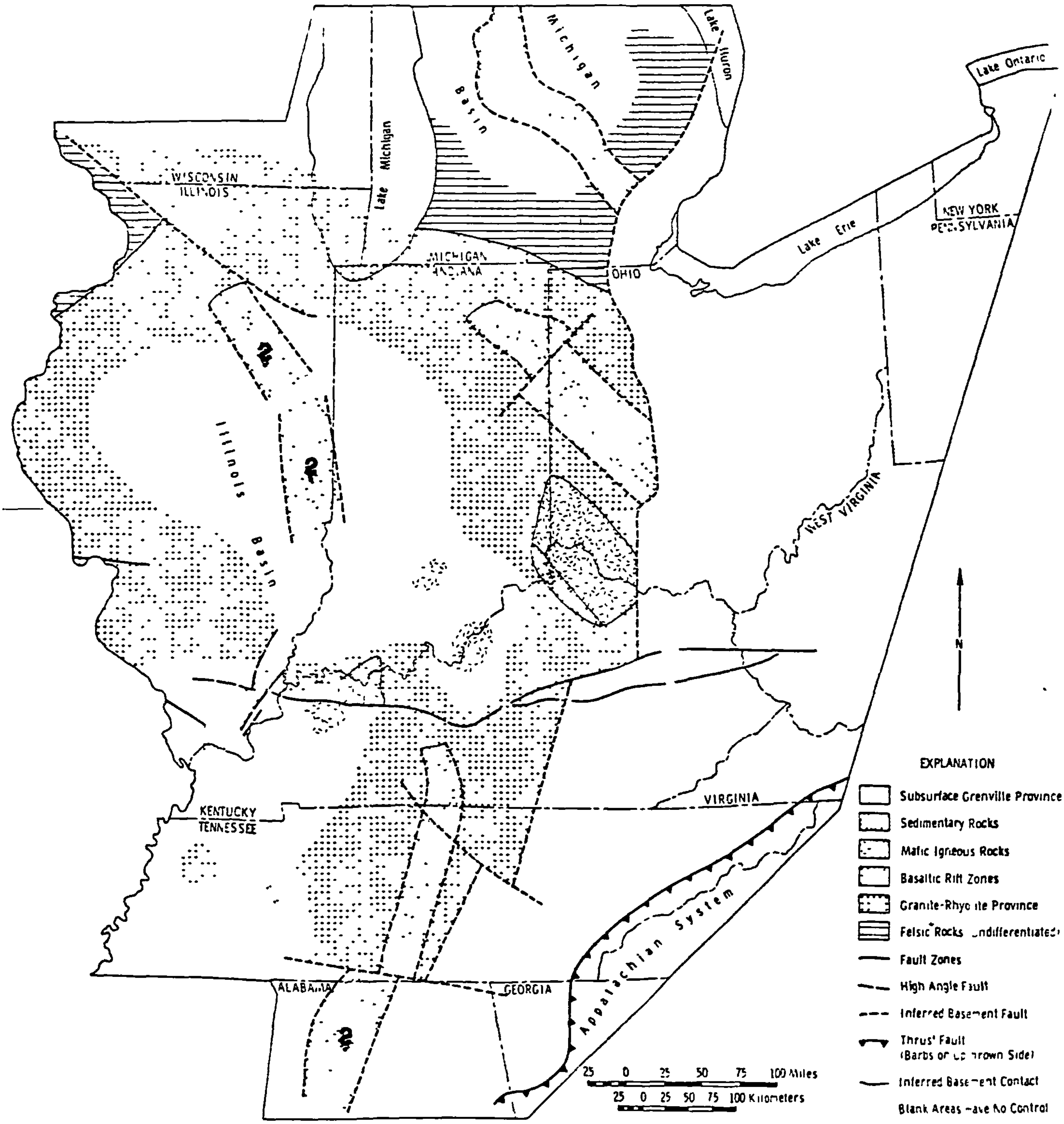
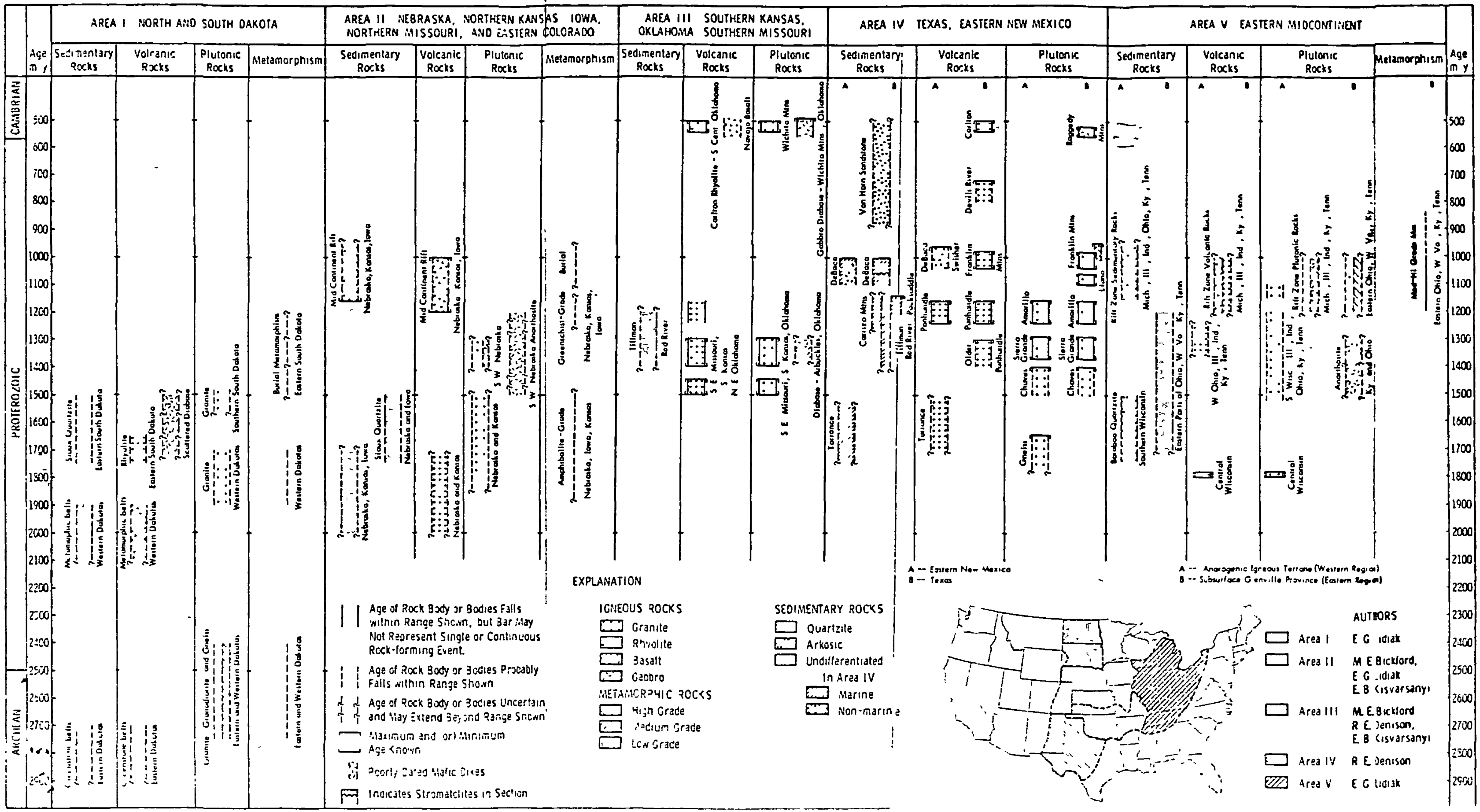

Lake Huron
Lake Ontario
Michigan Basin
Lake Michigan
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
Lake Erie
NEW YORK
PENNSYLVANIA
Illinois Basin
WEST VIRGINIA
KENTUCKY
TENNESSEE
VIRGINIA
ALABAMA
GEORGIA
Appalachian System
N
EXPLANATION
Subsurface Grenville Province
Sedimentary Rocks
Mafic Igneous Rocks
Basaltic Rift Zones
Granite-Rhyolite Province
Felsic Rocks Undifferentiated
Fault Zones
High Angle Fault
Inferred Basement Fault
Thrust Fault
Inferred Basement Contact
Blank Areas Have No Control
25 0 25 50 75 100 Miles
25 0 25 50 75 100 Kilometers

Fig 5

CORRELATION CHART FOR THE CENTRAL INTERIOR REGION

BY.
R. E. DENISON, E. G. LIDIAK, M. E. BICKFORD, E. B. KISVARSANYI



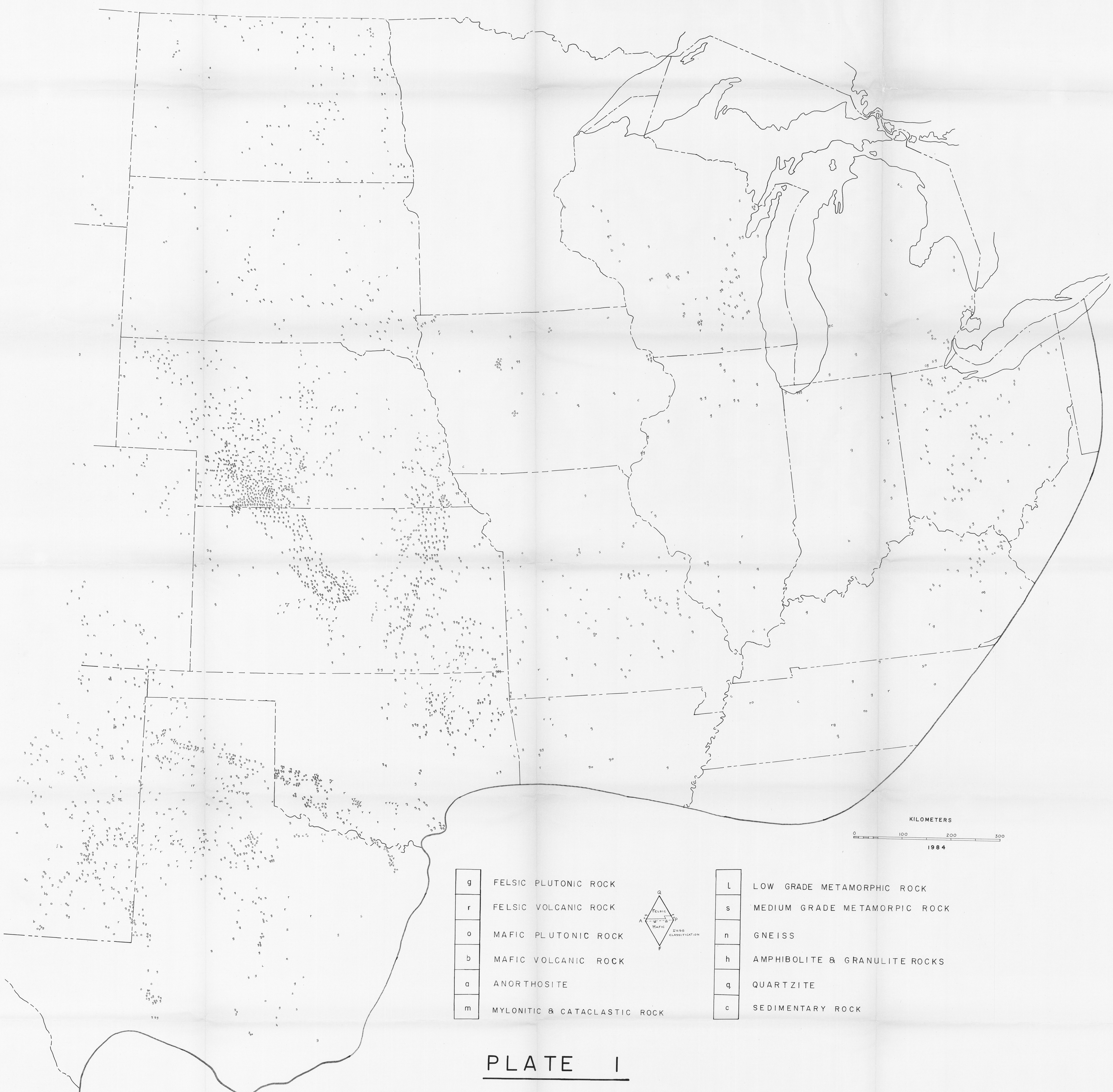


PLATE I

WELLS TO BASEMENT

IN THE INTERIOR OF THE UNITED STATES

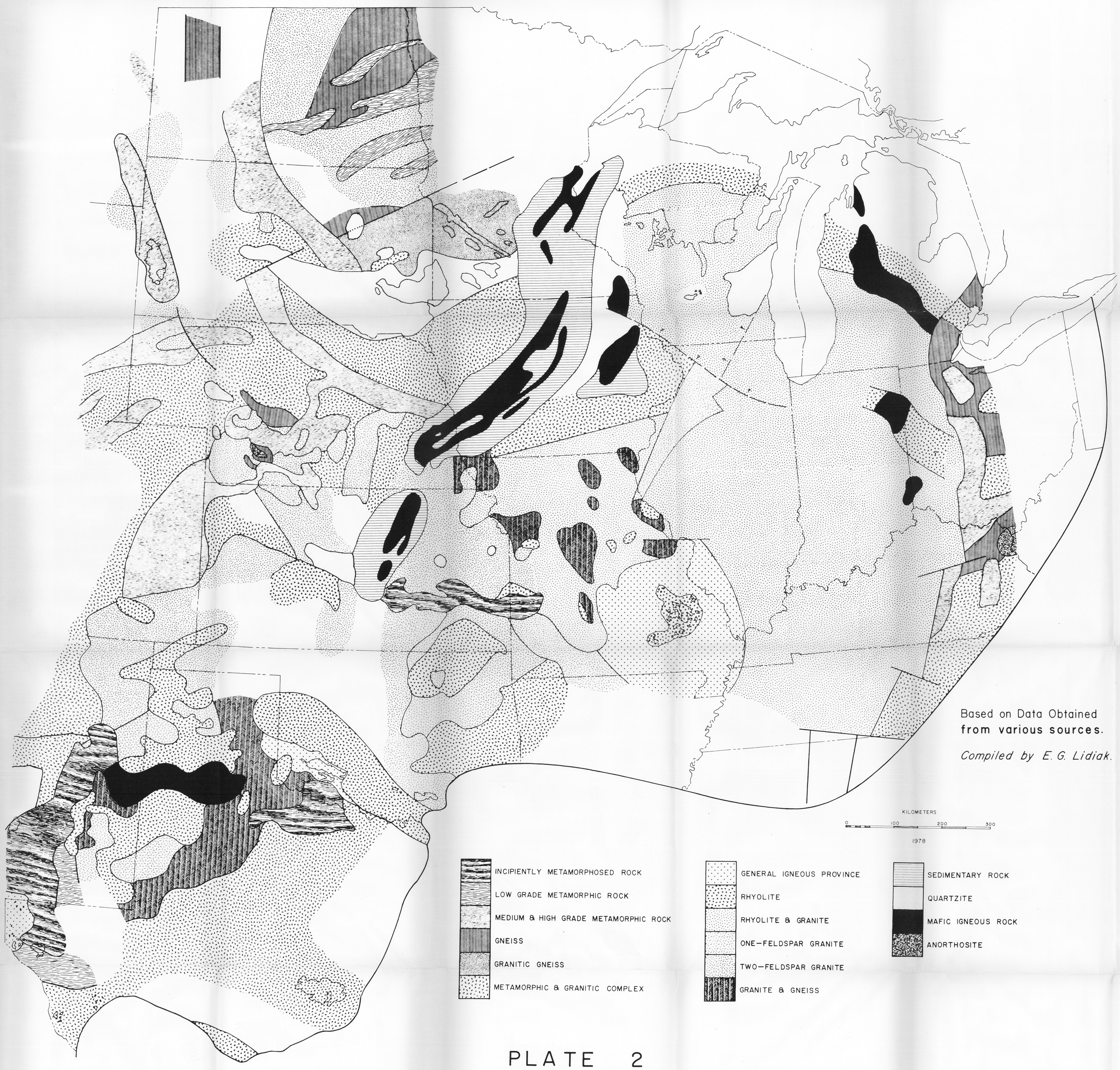


PLATE 2

BASEMENT ROCK MAP

OF THE INTERIOR OF THE UNITED STATES

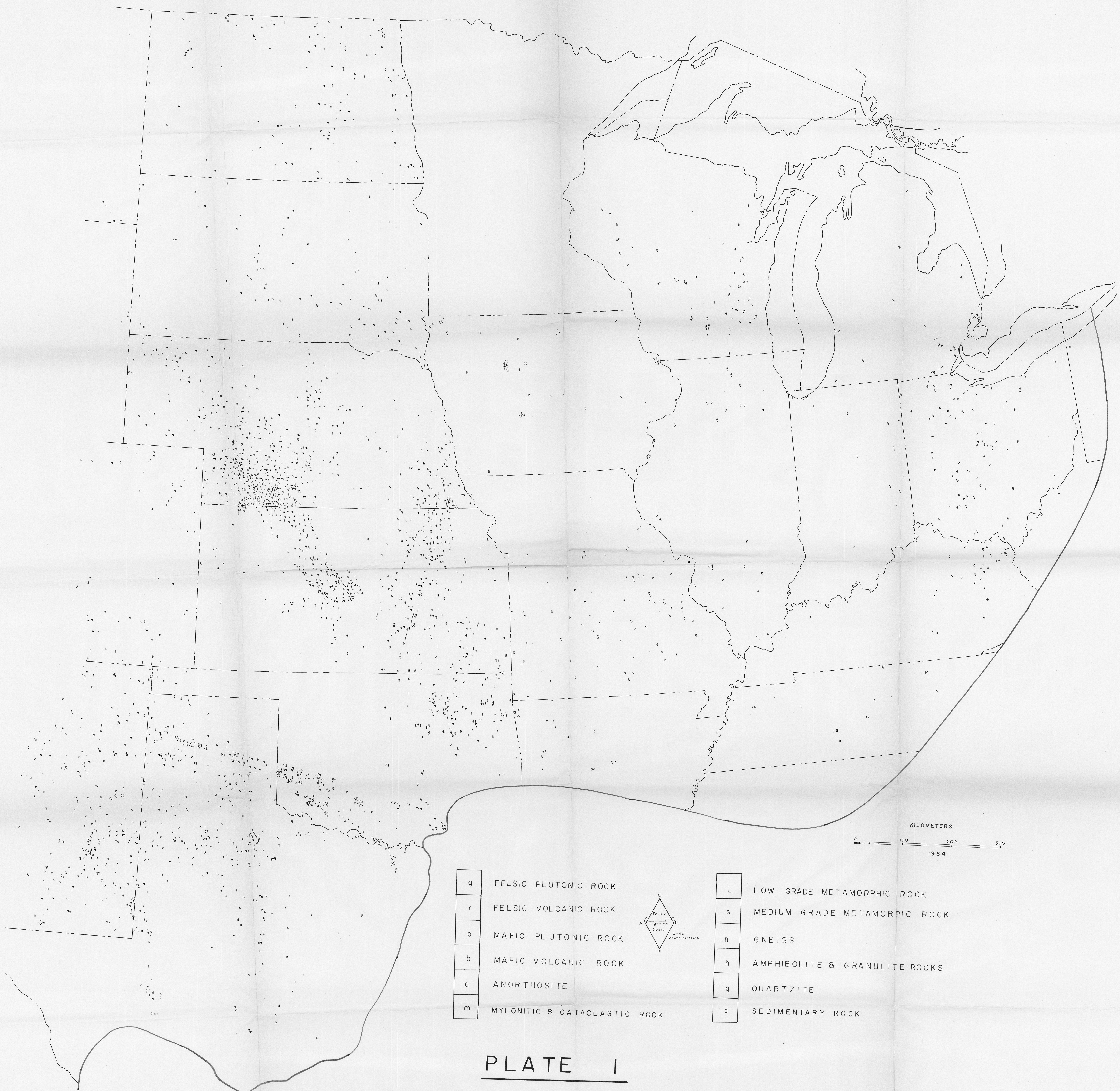


PLATE I

WELLS TO BASEMENT

IN THE INTERIOR OF THE UNITED STATES

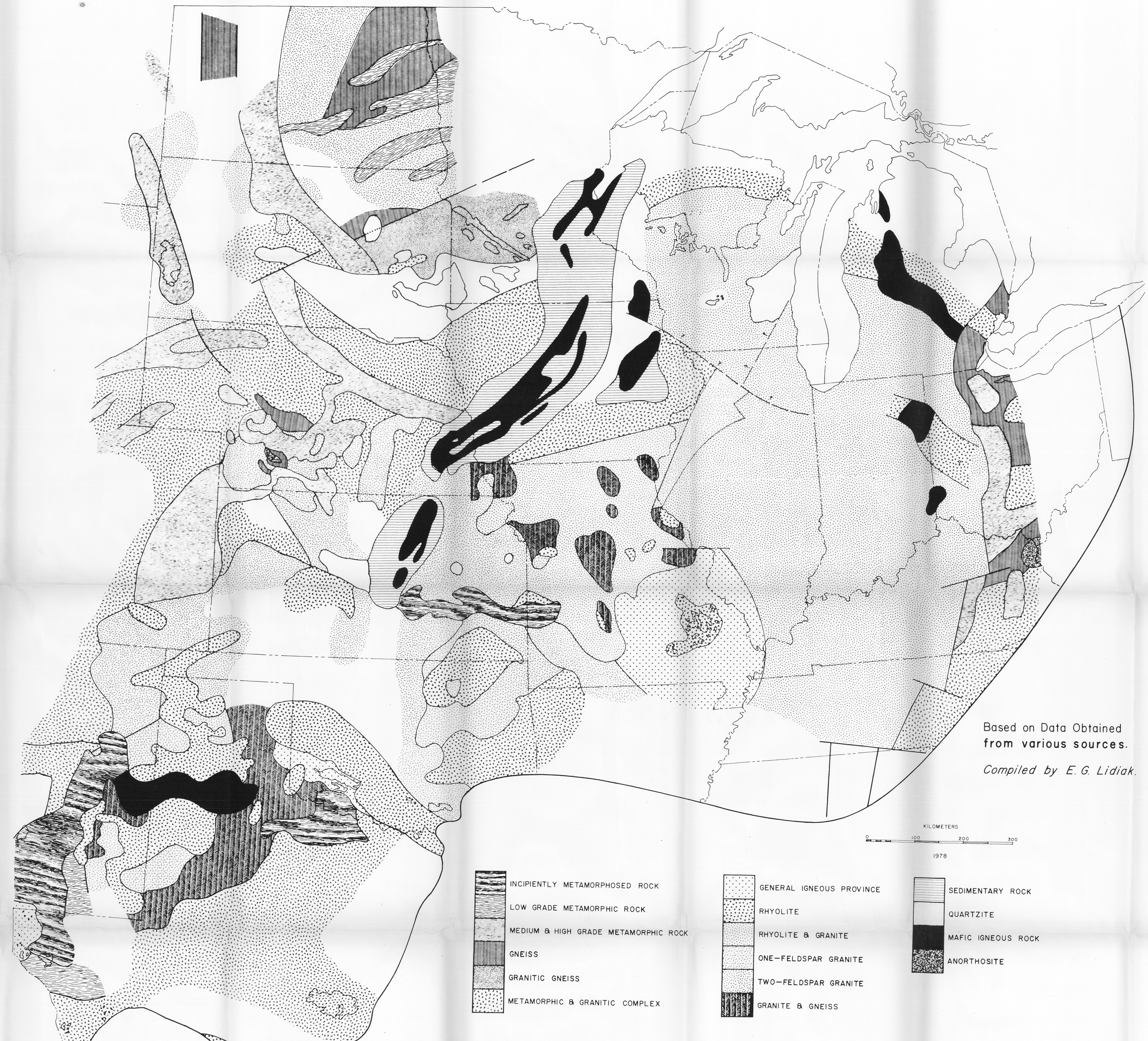


PLATE 2

BASEMENT ROCK MAP

OF THE INTERIOR OF THE UNITED STATES